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# OUR
# FACTORIES, WORKSHOPS,
# AND
# WAREHOUSES.

OUR

# FACTORIES, WORKSHOPS,

AND

# WAREHOUSES,

THEIR

## SANITARY AND FIRE-RESISTING ARRANGEMENTS.

BY

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TO

THE EARL OF SHAFTESBURY, K.G.,

WHO, BY HIS GREAT AND MAGNANIMOUS EFFORTS TO AMELIORATE THE
PHYSICAL AND MORAL CONDITION OF THE BRITISH FACTORY
AND WORKSHOP OPERATIVES,

HAS WON THE ESTEEM AND GRATITUDE OF ALL TRUE PATRIOTS,

This Book

IS (WITH PERMISSION) RESPECTFULLY DEDICATED.

# INTRODUCTION.

GREAT attention has of late years been paid to the sanitary condition and improvement of dwellings. This branch of sanitation is undoubtedly of vital importance, yet the sanitary condition of our hives of industry deserves at least equal consideration.

Although great sanitary projects have been carried out throughout the United Kingdom under the provisions of the Sanitary Acts, yet the death-rate percentage in our manufacturing towns shows very little decrease. The principal cause of this is unquestionably the prevalent insanitary arrangements of factories and workshops.

If we are to compete successfully against the Americans and Continentals for foreign markets, we must carefully preserve the vigour of our workpeople.

The British navvy and agriculturist are proverbial for their splendid physique and great powers of endurance, and it is only the British factory and workshop operative who is deficient in health and physique. If the operative worked in perfectly sanitary workshops, his vigour, thanks to our bracing atmosphere, should be as superior to that of the Continental operative as is the physique and vigour of the sturdy British navvy to that of the French.

The Continentals can and do obtain all the improved arrangements of applied machinery, the result of British ingenuity, but they cannot transplant the healthy and bracing atmosphere of the British Islands.

The majority of French manufacturers, thanks to the labours of their illustrious compatriot, General Morin, have not neglected sanitary measures, and the French workshops have a decidedly high reputation for healthiness.

The Americans—who promise to become our greatest competitors for the markets of the world—have for long been careful of the vigour of their workpeople. The following is an account of a visit to Lowell by the late Charles Dickens:—

"There are several factories in Lowell, each of which belongs to what we should term a company of proprietors, but what they call a corporation.

"I went over several of these, such as a woollen factory, a carpet factory, and a cotton factory, examined them in every part, and saw them in their ordinary working aspect, with no preparation of any kind or departure from their ordinary everyday proceedings. I may add that I am well acquainted with our manufacturing towns in England, and have visited many mills in Manchester in the same way. Arrived at the factory just as the dinner-hour was over. The working girls were all well dressed, but not, to my thinking, above their condition; for I like to see the humbler classes of society careful of their dress and appearance.

"These girls, as I have said, were well dressed, and that expression necessarily includes extreme cleanliness. They had serviceable bonnets, good warm cloaks and shawls, and were not above clogs and pattens; moreover there were places in the mill in which they could deposit their things without injury, and there were conveniences for washing.

"They were healthy in appearance, many of them remarkably so; and had the manners and deportment of young women, and not of degraded beasts of burden.

"The rooms in which they worked were as well ordered as themselves. In the windows of some there were green plants, which were trained to shade the glass; in all the rooms there was as much fresh air, cleanliness, and comfort as the nature of the occupations would possibly admit.

"Out of so large a number of females, many of whom were only just verging upon womanhood, it may reasonably be supposed that some were delicate and fragile in appearance; no doubt there were. But I solemnly declare, that from all the crowds I saw in the different mills that day, I cannot recall or separate one young face that gave me a painful impression."

Although the Factory Acts have proved to some extent beneficial, yet the sanitary arrangements of the majority of our factories and workshops are disgracefully defective.

This fact was most decidedly proved by the evidence which was tendered before the Parliamentary Commission of Inquiry in 1876.

The labour of most of our various branches of manufacture, if relieved from the insanitary accompaniments, would not be nearly so exhaustive—a fact of importance if foreign competition becomes more pressing, and longer hours of labour an unfortunate necessity.

As to accidents: they are as numerous as ever, owing to the absence of, or insufficient and defective, fencing, and also owing to ignorance of the operatives in the manipulation of belting, the art of lubrication, &c.

The Employers' Liability Act, 1881, will no doubt compulsorily excite the desire for more knowledge on the subject of the prevention of accidents, and the chapters devoted to this subject may offer some useful hints to an inquirer.

Every factory or workshop destroyed by fire represents so much skilled and valuable labour irrevocably lost to the nation; and every conflagration is a real disaster to the British public, which they can ill afford in this era of increasing foreign competition.

The chapters on this subject will, it is hoped, promote the construction of mills which will resist fire, and the adoption of arrangements of suppression in case of outbreak.

A good deal of misapprehension exists as to what is and what is not fireproofing. The chapters on this subject contain criticisms of the methods of fireproofing now before the public, and will no doubt assist manufacturers and others in discriminating between the real and false systems.

The author feels it incumbent upon him to acknowledge his obligations to the Société Industrielle de Mulhouse for very valuable information respecting the prevention of accidents.

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# OUR
# FACTORIES, WORKSHOPS,
# AND
# WAREHOUSES.

## PART I.

### HOW THE DEVELOPMENT OF ENGLISH MANUFACTURING INDUSTRIES AFFECTED THE HEALTH OF THE ENGLISH OPERATIVES AND COMPELLED LEGISLATIVE INTERFERENCE.

As far back as the date of the Phœnician commercial supremacy, galleys traversed the seas for the famous tin of Cornwall; probably the mineral wealth of Britain was the attraction which influenced the Roman emperor to subjugate the country. From the time of the Roman evacuation of Britain to the twelfth century, the only articles exported from Britain were minerals and wool, and these in very insignificant quantities. Owing to bad governments and tyrannical barons, the people had no encouragement to develop the valuable national resources of the country.

In the twelfth century, a few exiles from Flanders settled in Worsted, and introduced the art of spinning woollen yarn. This article of manufacture was afterwards known by the name of the town where it was introduced. This industry received little encouragement, and made little progress during the turbulent twelfth century.

Many inventions were introduced into England, brought by the Red Cross knights from the East on their return from the Crusades—among them the invention of windmills.

During the reign of Edward I. great commercial progress was made, and Venetian and Florentine merchants settled in London and carried on an extensive trade in English wool, lead, and tin, in exchange for silks, wine, cotton, and other Venetian manufactures.

The commerce was extended by the crusaders in Edward I.'s reign, who opened out new oriental markets, improved navigation, and introduced many inventions.

In 1331, weavers from Brabant, in the Netherlands, settled in York, and introduced the manufacture of cloth; and a few years later looms were established by one Thomas Blanket for the weaving of a certain description of cloth, afterwards known by his name.

To foster and encourage the manufacture of English cloth, Edward III. restricted the use of any but native manufactured cloth. The costume of the labouring population, however, up to the date of the Commonwealth was principally buff jerkins.

In the reign of Henry VIII. a German, named Jurgen, invented the spinning-wheel, and in the same reign the manufacture of cotton thread was introduced.

In the reign of Elizabeth (sixteenth century), the Rev. William Lee, of Nottingham, invented the stocking-frame, but his invention made him odious to the stocking knitters, and he was compelled to leave England for France, where he soon died of a broken heart and in abject poverty. During Elizabeth's reign many discoveries were made. Alum was found near Whitby, and gave a great impetus to the industry of dyeing and tanning. A German, in this reign, invented mills for producing paper.

Weaving, which had long been in a languishing condition, once more began to revive in England, and the various industries received further impetus by the arrival of skilful operatives from the Low countries, driven into exile by the Spanish persecutions.

Although the people engaged in industrial occupations were gradually becoming a power in the land, the tyrannical laws and the constant wars prevented any great progress in the extension of the arts and manufactures until the peaceful reign of James I., when commerce extended and the arts of industry prospered.

During the reign of James I., the manufacture of broad silk was introduced into England: this monarch instituted the experiment of the cultivation of the mulberry in England, but the attempt was a failure.

The revocation of the edict of Nantes caused nearly a million of the most powerful and industrious citizens of France to settle in England, the Netherlands, Switzerland, and Germany. The native English jealousy caused them to be received with less welcome in England than elsewhere, although 50,000 are said to have settled in various parts of England, and by their skill and industry stimulated and founded branches of textile manufacture which have since been of national importance.

In the reign of Charles I., the manufacture of Irish linen was established.

During the Commonwealth, owing to the extended liberties of the people, industry and commerce were exceedingly prosperous; buff jerkins were mostly dispensed with by the people, and cloth was extensively worn.

While the Venetian Republic was slowly degenerating from its supremacy, the industry and commerce of the Dutch were making rapid strides, and about the close of the sixteenth century the Dutch were unrivalled in the arts of industry. Many of the Dutch, in the reign of Charles II. settled in England, introducing several important inventions; among them was Sir Thomas Loom, who introduced the Dutch device for weaving into England, ever after known by his name.

The art of dyeing *as practised by the Dutch* was also introduced by Anthony Brewer. At the beginning of the seventeenth century, Lombes, of Norwich, secretly visited

Leghorn (at this time famous for the manufacture of silk), with the intention, if possible, of ascertaining the method of manufacture, and after many ingenious and dangerous strategies he succeeded, and introduced the method of manufacture into England.

Cotton wool was introduced into England in the seventeenth century, and records exist of imports of the material from Cyprus and Smyrna worked into fustians and vermilions by the weavers of Lancashire, and often re-shipped into the East. Venetian and Florentine looms had long ceased to produce cloth, and England was destined to take the position of the once famous Venetian Republic.

In the early part of the seventeenth century two new branches of manufacture were introduced, e. g. thread manufacture was established in Scotland, at Paisley, and an establishment was opened by Frenchmen in London for the manufacture of carpets.

The use of water for motive power by means of water-wheels was very general at this epoch, more especially, however, for grinding corn, although many textile manufacturers utilised the power in various ingenious ways, and the choice of a site for a manufactory was greatly influenced by the presence of a good stream of water.

The manufacturers had their homes and weaving appliances under one roof.

The weaving was generally carried on in the cottage chambers or attics; the husband commonly plying the shuttle, while the good-wife merrily turned a spinning-wheel, maybe chanting a homely ballad in accompaniment. (See Fig. 1.)

The busy whirl of the wheel, and the healthy faces of the spinners, must have presented a scene of quiet domestic happiness rarely equalled in this more enlightened age.

As the products of the looms were generally destined for local requirements, the buildings, at once workshops and dwellings, were scattered over farming districts, their number proportionate to the agricultural population. The buildings were ordinarily constructed of uncoursed rubble loosely walled and covered with a thatched roof, the windows and doors being mostly of the rudest description.

The inferior workmanship of these buildings happily allowed free ventilation, which, coupled with the ordinary normal temperature of the atmosphere, prevented any deterioration of the physique of the workers, who were as healthy and robust as the sturdy agricultural yeomen who were their principal customers.

Where motive power other than manual was employed, the health of the workers would not probably be so good, except in the case of windmills, as these structures were generally erected on high eminences, and, therefore, the foundations would be dry and ventilation would be sufficient. From the proverbially light-hearted character of the jolly miller of bygone days, we may fairly assume that his occupation must have been healthy.

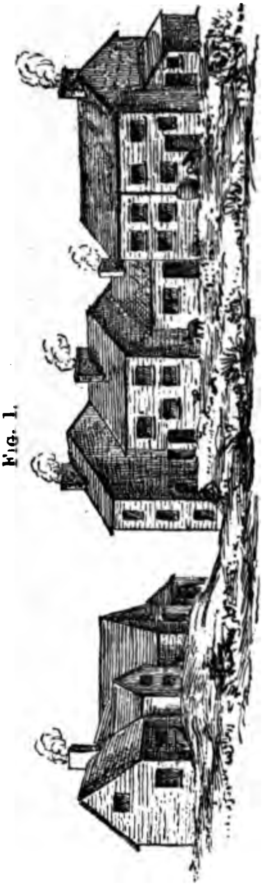


Fig. 1.

COTTAGE WORKSHOPS (HANDSPINNING & WEAVING
TONG FOLD near BOLTON LANCASHIRE.

Towards the close of the seventeenth century, Watt successfully applied steam as a motive power. This great invention was destined to have a gigantic influence on the progress of industry. Almost simultaneously with the discovery and application of Watt's great invention, the illuminating quality of coal gas was discovered, followed by a gradual and afterwards rapid application. The importance of the mineral wealth of England was at this time more generally becoming appreciated; and in the midland and northern counties the application of iron for construction and mechanical purposes was gradually extending.

Another invention, the spinning jenny, destined to revolutionise the process of textile manufacture, was invented and applied towards the termination of the seventeenth century. Difference of opinion exists as to who was the original inventor of this ingenious spinning machine. From researches in the records of patents, letters patent appear to have been taken out in 1738 by one Lewis Paul, for a machine to spin. The name of John Wyatt, a mechanic, appears as a witness to the signature of the patentee. Wyatt and Paul entered into partnership for the purpose of practically developing the machine. Wyatt appears to have been the real inventor, and Lewis Paul pretending to possess sufficient capital to practically develop the machine persuaded Wyatt to allow him to patent the invention. Lewis Paul proved to be a mere adventurer, and from want of capital the patent was lost.

About ten years later the same Lewis Paul brought out a carding machine, which eventually became adopted in Lancashire. In the year 1738 the fly shuttle was invented by a Mr. Kay. Up to the date of this invention weavers were accustomed to throw the shuttle from hand to hand through the meshes—a laborious and clumsy method. Kay's invention was a mechanical arrangement for throwing the shuttle, and was rapidly and extensively adopted.

Mr. James Hargreaves, a weaver in Blackburn, succeeded in inventing a machine for spinning wool in the year 1767; and in the same year a reed maker named Thomas Hughes invented a machine called the water-frame throstle, for the spinning of twist by rollers. Two years later Robert Arkwright applied for letters patent for a machine also for spinning wool.

In 1768 James Hargreaves commenced to employ his machine in a small way; his fellow-weavers, afraid of the invention, attempted to dissuade him from improving his machine; further improvements they thought might eventually deprive them of a means of living by their craft. Hargreaves, however, despite opposition, persevered with continued success; his fellow-workmen became exasperated, and, in retaliation, forcibly entered the inventor's workshop and destroyed his machine.

Hargreaves, disgusted at the outrage, removed to Nottingham, and eventually entered into partnership with a capitalist; a building was at once erected and the celebrated jenny was practically applied. A year later Hargreaves effected considerable improvement to his invention. Paul's carding machine was soon after adopted by Mr. Peel; the latter gentleman, combining with Mr. Hargreaves, brought out the machine with cylinders.

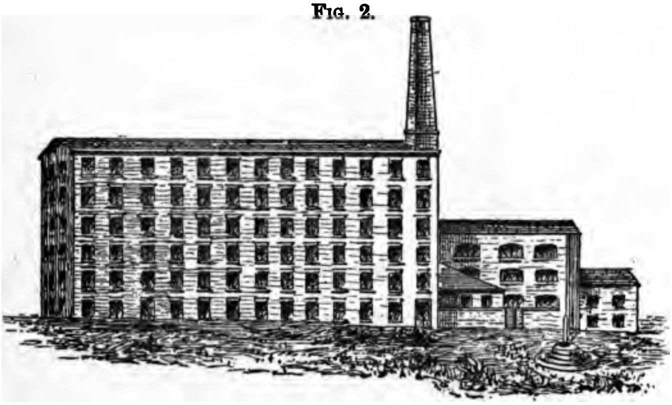
The great inventors were now constantly improving their respective machines; Arkwright was especially successful, and from this era the erection of cotton-mills commenced. The cottage workshops were far too small for the improved machines, and the inventors were fully cognisant of the value of concentration in the arrangement of their machines.

The first mills were erected by Hargreaves at Nottingham, the motive power was supplied by horses. Others were erected at Cromford, the motive power was produced by a more general form of prime motor at this time, e. g. the water-wheel. The small manufacturers, with the ancient and clumsy machinery, were unable to compete with the wonderful productions of the new inventions, and it is not surprising that they exhibited the most bitter hatred both against the new machines and the inventors.

The transition of individual to concentrated methods of working destroying, as it did, the independence of the majority of the small manufacturers, produced a crisis in the industrial history of England. Violations of mill property, and even murders, were frequent.

The former cottage workshops, generally erected on dry and healthy soils and on high eminences, were healthy, and the hours of labour were unlimited, and not over exhaustive; on the other hand, the new mills were

FIG. 2.



HALLIWELL AND SHARPLES MILLS, ASTLEY BRIDGE.-LANCASHIRE.

erected, in many instances, on morasses in close proximity to water, or on damp soils (see Fig. 2). The rooms were exceedingly low and deficiently lighted. These pioneer mills were veritable dens of death. Added to their enumerated sanitary defects, the parvenu masters, generally avaricious and cruel, held despotic sway over the operatives, who were helpless, as remonstrance or protest from the poor workers met with instant dismissal. The wages were decreased to starvation level. Where possible, apprentices were employed to replace adults; the whole system of labour was brutal and heartless in the extreme.

This system of slave driving was too outrageous to be of long duration; the press of 1790 drew attention to the barbarities. Unfortunately, the excess practised by the demons of the French Revolution occurring at this time horrified the British public, who, timidly fearing a similar outbreak on the part of the oppressed operatives, unheeded the heart-rending appeals for justice. Sir Robert Peel, who was one of the foremost to manufacture by the new system, brought forward the first bill for the amelioration of the factory workers in 1802. This bill eventually became law; the provisions of the bill, however, mostly affected the apprentices.

The principal clauses of the act were as follows:—

1. The ventilation and washing of factories.
2. Limitation of hours of labour to twelve hours a day.
3. No night labour to be permitted.
4. The education of apprentices.
5. Separation of sexes.
6. Appointment of visitors to factories with requisite powers.

In 1775 the mule was invented by a Mr. Crompton of Bolton.

In 1785 the patent rights of Sir Richard Arkwright's invention were annulled by a decision of the Court of King's Bench, and all the accumulated improvements thrown open to the trade.

In 1787 a Mr. Cartwright brought into successful action the power loom.

Another great invention, that of the steam engine, had rapid development and application. Henceforth the spinning and water-wheel were to be supplanted by the massive fly-wheel of the steam engine driving its countless thousands of spindles.

This invention enabled manufacturers to erect their mills in almost any position, and to evade the beneficent clauses of Peel's Factory Act. Mills were erected in populous districts, and the children of the neighbouring poor employed in preference to the apprentices. And gradually the slave-driving system was re-established, the acts which were framed for apprentices were evaded, and non-apprentices could be treated with impunity without infringing any of the clauses of the act.

In order to meet this general and wicked evasion Sir Robert Peel, in 1815, promoted a Committee of Inquiry into the prevalent abuses of the Factory Acts. The evidence tendered proved beyond doubt the existence of great abuses; the forcible evidence of Sir Robert Peel, one of the witnesses before the Committee of Inquiry, is worth repeating, as tending to show how the provisions of the act were evaded:—

"Large buildings are now erected, not only as formerly on the banks of streams, but in the midst of populous towns; and instead of parish apprentices being sought after, the surrounding poor are preferred, whose masters, being free from the operations of the former act, are subjected to no limitation of time in the prosecution of their business."

Sir Robert finally terminated his evidence as follows:—
"And this great effort of British ingenuity, whereby the machinery of our manufactures has been brought to such perfection, instead of being a blessing to the nation, will be converted into the bitterest curse."

The Factory Act of 1819 was the result of the Commission of Inquiry; the act provided that no child under nine years of age be allowed to work in a cotton factory, and made the provisions of the former act applicable to all cotton operatives.

A further amendment prohibited a person under eighteen years of age from working sixty-nine hours in each week. It will be noticed that the acts were applied to cotton operatives only, although great abuses were practised on operatives engaged in silk, woollen, and other textile factories.

The remarkable inventions, at first only applied to cotton manufacture, were successfully applied to the manufacture of other textile material. The fulling-mills and brushing-machines were invented for woollen textures.

Machines for arranging the threads of the warp were perfected by Messrs. Ross and Radcliffe. The manufacture of cards was also perfected.

In 1801 Joseph Marie Jacquard, a Frenchman, brought forward his wonderful self-acting loom for weaving brocade and figured silks. By a curious arrangement of piercing thick cards with holes of any desired pattern the most complicated and elaborate designs can be imitated.

The bobbin net machine was introduced by Heathcote in 1809, and in combination with the Jacquard arrangement it revolutionised the lace trade.

Formerly the greater part of the cotton manufactured in England was bleached by the Dutch, but by the discovery of the bleaching quality of chlorine the bleaching operation was completely transformed, and bleaching works were at once erected in England.

The inventions of Watt, Hargreaves, Arkwright, and others were, some time after their application to cotton, equally applied to the manufacture of woollen, &c., and mills were erected in Yorkshire.

The same transition of method of manufacture occurred as in the case of cotton, followed with similar cruelties. Unfortunately these victims of oppression had not, like their brethren the cotton operators, any magnanimous champion to remove their grievances.

Although Sir Robert Peel's amended act proved inadequate to remove all the atrocities practised on the cotton operatives, yet the provisions of the act had a beneficial effect on the health of the operatives.

Sir John Hobhouse succeeded in passing, in 1825, an enactment for reducing the hours of labour on Saturday from twelve to nine, and for imposing penalties for infringement of the clauses of the Factory Acts.

Some years passed, and the decided improvement in the health and physique of the operatives encouraged renewed agitation for additional remedial legislation, which was further stimulated by the agitation which was gradually rising in Yorkshire.

The agitation of the woollen operatives was led by Mr. Oastler, subsequently known by the name of the King of the Factory Children.

In the year 1830, Mr. Oastler published in the 'Leeds Mercury' an eloquent exposé of the wrongs and abuses inflicted on the operatives of the West Riding. These letters fanned the growing agitation into a great and enthusiastic one, and crowded meetings were continually held throughout the West Riding. Sir J. Hobhouse represented the agitators in Parliament, and with Lord Morpeth framed a bill to limit the hours of working to eleven and a half hours in any one day, and eight and a half on Saturdays, with provisions for hours of refreshment, and prohibited any person under eighteen from working beyond those hours. The application of this bill was extended to cotton, woollen, worsted, flax, and silk factories. This bill met with the unanimous approval of the operatives of the various trades interested.

The Scotch flax and West of England woollen factory masters strongly opposed the bill. The principal objections were that the manufacture of worsted yarn was a more healthy occupation than that of cotton, and, on commercial grounds, that the passing of the measure would foster foreign competition and prove disastrous to the woollen and linen manufacturers. They further, and with some justice, objected to over legislative interference as pernicious and discouraging to manufacturing enterprise. The opposition proved successful, and after several modifications and amendments, the provisions of the existing Factory Acts were still made applicable only to cotton factories.

This act, by its beneficial effect on the cotton operatives, proved a further stimulus to the Yorkshire and other operatives who were not under its protection to renewed agitation, this time led by Mr. Sadler, M.P. for Newark. This benefactor framed and introduced, in 1831, the famous measure known as the Ten Hours Bill. His speech moving the second reading of his bill is remarkable for its eloquence, and would move the hardest heart to compassion.

A few sentences culled from his speech will serve to show the condition of the woollen operatives at this time:—

"Hence (he says) at this late hour, while I am thus fully but earnestly pleading the cause of oppressed children, what numbers of them are still tethered to their toil, confined in heated rooms, bathed in perspiration, stunned with the roar of revolving wheels, poisoned with the noxious effluvia of grease and gas, till at last, weary and exhausted, they turn out almost naked into the inclement air, and creep shivering to beds from which relays of their young fellows have just risen; such, at the best, is the fate of many of them, while in numerous instances they are diseased, stunted, crippled, depraved, and destroyed."

Great was the disappointment of the anxious operatives when Parliament, instead of making the bill law, decided to institute a commission to inquire into the subject.

The evidence brought before the committee in proof of the barbarities commonly practised may be understood when it is known that the committee sat throughout the whole period of the session.

The progress of the bill was further retarded by the great Reform Bill, which, by its magnitude and universal importance, absorbed all other interests.

To the consternation of the anxious operatives, the general election following the Reform Bill, resulted in the unseating of their champion, the illustrious Sadler.

Lord Ashley (Shaftesbury), a staunch supporter of the Ten Hours Bill, now, and to the delight of the operatives, undertook the charge of the measure.

By Lord Ashley's energetic efforts in Parliament, supplemented by the efforts of Messrs. Sadler and Oastler in the country, the nation became thoroughly aroused to the scandalous abuses practised on the unfortunate operatives.

In order to meet the growing national agitation, the manufacturers proposed that a Parliamentary Commission should be appointed to receive evidence, and finally decide as to the best means to remedy the existing evils.

This proposal was indignantly opposed by the operatives, who considered it still another stratagem for delay, and they issued eloquent protests against the proposal, calling attention to the fact that a table deduced from evidence tendered before former inquiries gave ample proofs that more operatives of all ages had died before their twentieth year from the time the factory system prevailed than had died at forty when the factory system did not exist. An immense assemblage of operative children gathered together at Manchester to present a memorial to the Committee of Inquiry, who were then sitting at that town. The tenor of the memorial will be understood from the following extract:—

"We implore your pity and compassion for our suffering; for the great weight of labour thrown on our young limbs; for the long duration of labour, mostly in the close air of a heated room."

Other and similar demonstrations of protest and appeal were arranged in the Yorkshire towns.

The decision of the committee was as follows:—

They found that in all branches of manufacture, children worked the same number of hours as the adults, and that owing to excessive fatigue the operatives were physically and morally degenerating; and that evidence proved conclusively that legislation on behalf of the children in factories was necessary.

Lord Ashley introduced another bill in 1833, limiting the hours of labour for young persons to ten hours a day; but this bill met with successful opposition, and was rejected in preference to one framed upon the basis of the report of the Commission of Inquiry. This latter bill was made law in the year 1836. The most important clauses were as follows:—Prohibiting the employment of children in factories under thirteen years of age; but with a proviso that, in mills for the manufacture of silk, children under the age of thirteen years should be allowed to work ten hours in any one day.

This act, known as Lord Althorp's, proved a very impracticable and unsatisfactory measure. The clauses were defectively drawn up and easy to evade.

Demonstrations were continually held by the operatives, at which resolutions were passed denouncing Lord Althorp's Act. The masters were also at work to prevent further remedial legislation, and they influenced the Vice-President of the Board of Trade to bring forward a bill to repeal the thirteen years clauses of Lord Althorp's Act. The introduction of this bill roused the dormant energies of the most lukewarm of the operatives and their advocates, and immense demonstrations were held throughout the manufacturing districts. The opposition proved effectual; the bill was withdrawn.

In 1838, Lord Ashley moved a resolution to this effect: "That the House deeply regrets that Althorp's Act, so imperfect and inefficient, had continued so long without amendment." This resolution was lost by the narrow majority of fifteen.

The operatives still continued to agitate, and meetings were constantly held passing resolutions in favour of the Ten Hours Bill, and no surrender.

Russell's Government brought forward a bill in 1839, containing the following proposed alterations and amendments to Althorp's Act, viz. that no child should work in more than one factory in one day; to give factory inspectors additional powers in checking forged certificates; and to abolish the clause giving power to mill occupiers to recover lost time, except when mills were driven by water power.

This bill received no support, and Russell's Government withdrew it.

The resignation of the Government in 1840 rendered abortive a motion proposed by Lord Ashley—that a committee be appointed to inquire into the operations of the Factory Acts.

The new Government was formed in 1842, and in 1843 the Secretary of State undertook the framing of a bill to finally settle the question.

This bill was to be applicable to silk and cotton operatives, and to reduce the hours of labour for children of nine to thirteen years, from eight hours to six hours and a half; young persons not to be permitted to work longer than twelve hours a day; on Saturdays nine hours: it also enforced the fencing of dangerous machinery. The educational clauses were unfortunately so objectionable, and met with such opposition, that the Government decided to withdraw the bill. The bill, in an amended form, was reintroduced in 1844, its application being extended to wool and flax mills.

The operatives, however, were not satisfied with the provisions of this Government bill, and great demonstrations of protest were held, denouncing the measure, and demanding the reduction of the hours of labour for all operatives to ten hours each day. That in the second clause of the bill "night" shall mean from six o'clock in the evening to six o'clock in the morning, which, after deducting the hours for refreshment, virtually meant the long-wished-for ten hours each day.

The famous Ten Hours Bill received the Royal Assent, and came into operation on the 1st of July, 1847.

An amendment to the act was proposed in July 1850, to prohibit the relay or shift system, by which the Ten Hours Bill had been in many places rendered nugatory. The amendment received the Royal Assent on July 26th, 1850.

Further amendments have been made from time to time to the Factory Acts.

The following is a list of the legislative enactments relating to factories and workshops up to the year 1880:

| Title of Act. | Session and Chapter. |
|---|---|
| An Act for the Preservation of the Health and Morals of Apprentices and others in Cotton Factories | 42 Geo. III. c. 73. |
| An Act to regulate the Labour of Children and Young Persons in the Mills and Factories of the United Kingdom | 4 William IV. c. 103. |
| An Amendment relating to Labour | 7 & 8 Vict. c. 15. |
| An Act eliminating certain Ropeworks from the operations of the Act | 9 & 10 Vict. c. 40. |
| A further Amendment relating to Labour | 13 & 14 Vict. c. 54. |
| An Act to further regulate the Employment of Children in Factories | 16 & 17 Vict. c. 104. |
| The Factory Act, 1856 | 19 & 20 Vict. c. 38. |
| An Act to extend the Application of the foregoing Acts to Lace Factories | 24 & 25 Vict. c. 117. |
| The Bakehouse Regulation Act, 1863 | 26 & 27 Vict. c. 40. |
| The Factory Acts Extension Act, 1864 | 27 & 28 Vict. c. 48. |
| The Sanitary Act, 1866 | 29 & 30 Vict. c. 90. |
| The Factory Acts Extension Act, 1867 | 30 & 31 Vict. c. 103. |
| The Workshops Regulation Act, 1867 | 30 & 31 Vict. c. 146. |
| The Factory and Workshops Act, 1870 | 33 & 34 Vict. c. 62. |
| An Act to exempt the Persons of the Jewish Persuasion from Penalties for Working on Sundays | 34 & 35 Vict. c. 19. |
| The Factory and Workshop Act, 1871 | 34 & 35 Vict. c. 104. |
| The Factory Act, 1874 | 37 & 38 Vict. c. 44. |
| The Public Health Act, 1875 | 38 & 39 Vict. c. 55. |
| The Elementary Education Act, 1876 | 39 & 40 Vict. c. 79. |

# PART II.

## ON THE EXISTING SANITARY ARRANGEMENTS OF TEXTILE AND OTHER MANUFACTURING OCCUPATIONS.

HOWEVER productive of greatness the industry of a nation may be, if the greatness is also a tax on the life of its producers from disregard of nature's laws, the greatness is false, and instead of exciting admiration should produce shame. The evidence recently laid before the British Parliament shows that, while about 100 deaths from phthisis and other lung diseases are occurring among men living in various English agricultural districts, at ages varying from fifteen to twenty-five, there occur in similar masses of population in Leicester, 171; in Nottingham, 192; in Preston, 220; in Manchester, 263; in Derby, 198; in Salford and Ashton-under-Lyne, 203; in Leeds, 218; in Rochdale, 193; in Macclesfield, 184.

In industries confined to female occupation, such as some silk industries and lace-making, &c., the atrocious sanitary arrangements produce terrible results in lung diseases.

In the following tables are enumerated the deaths from consumption of persons of various occupations, compiled from an excellent French work, entitled, 'Recherches Anatomiques sur l'Emphysème Pulmonaire.'

| | |
|---|---|
| Occupations with vegetable and mineral emanations | 176 |
| Occupations with various descriptions of dust | 145 |
| Sedentary life | 140 |
| Workshop life | 138 |
| Hot and dry air | 127 |
| Stooping position | 122 |
| Sudden movement of arms | 116 |
| Active life and muscular exercise | 89 |
| Exercise of voice | 75 |
| Living in open air | 73 |

RELATIVE FREQUENCY OF PHTHISIS PRODUCED BY DUST OF VARIOUS KINDS OR DEFICIENT VENTILATION IN 100 PATIENTS. Compiled from a work by Dr. Hirt, entitled, 'Die Krankheiten der Arbeiter,' Leipzig, 1873.

| *Metallic Dust-producing Occupations.* | Percentage suffering from Phthisis. |
|---|---|
| Needlemakers | 69·6 |
| Filemakers | 62·9 |
| Lithographers | 48·5 |
| Callender makers | 42·1 |
| Grinders | 40·4 |
| Moulders | 36·9 |
| Watchmakers | 36·5 |
| Typefounders | 34·9 |
| Engravers | 26·3 |
| Dyers | 25·0 |
| Varnishers | 25·0 |
| Painters | 24·5 |
| Printers | 21·6 |
| Beltmakers | 19·7 |
| Tinmen | 14·1 |
| Pinmakers | 12·5 |
| Cutlers | 12·2 |
| Locksmiths | 11·5 |
| Farriers | 10·7 |
| *Mineral Dust-producing Occupations.* | |
| Flintcutters | 80·0 |
| Grindstone makers | 40·0 |
| Plasterers | 19·0 |
| Porcelain workers | 16·0 |
| Potters | 14·7 |
| Carpenters | 14·4 |
| Masons | 12·9 |
| Diamond workers | 9·0 |
| Cement „ | 8·10 |
| *Vegetable Dust-producing Occupations.* | |
| Cigar workers | 36·9 |
| Weavers | 25·0 |
| Ropemakers | 18·9 |
| Joiners | 14·6 |
| Coachmakers | 12·5 |
| Pastrycooks | 11·6 |
| Millers | 10·9 |
| Bakers | 7·0 |
| Chimney sweeps | 6·5 |
| Charcoal burners | 2·0 |
| Coal miners | 0·0 |

### *Animal Dust-producing Occupations.*

| | Percentage suffering from Phthisis. |
|---|---|
| Brushmakers | 49·1 |
| Hairdressers | 32·1 |
| Upholsterers | 25·9 |
| Turners | 16·2 |
| Button makers | 15·0 |
| Hatters | 15·0 |
| Harness makers | 12·8 |

### *Mixed Dust-producing Occupations.*

| | |
|---|---|
| Workers in glass | 35·0 |
| Journeymen | 15·1 |

### *No Dust.*

| | |
|---|---|
| Shoemakers (deficient ventilation) | 18·7 |
| Brewers | 11·2 |
| Coopers | 10·1 |
| Glovers | 10 0 |
| Farmers | 9·2 |
| Butchers | 7·0 |

These tables show that mineral and metallic dusts are the most dangerous; the finer the metallic dusts, the greater the evil.

It will be seen that the effect of coal dust is harmless; carbon, or coal, acting as a preservative.

Of the vegetable dusts, the fibres of cotton are decidedly the most hurtful, and have a serious effect on the lungs, producing irritation of the larynx, coughing, and expectoration of a spula containing the fibres of cotton. The hurtful effects of inhalation of cotton fibres are greater on females than males. The dust of wheat, barley, and corn, when inhaled in great quantity, causes bronchitis, &c. Millers generally suffer from pneumonia, occasionally produced by the inhalation of the dust. The dust arising from the manufacture of linen and hemp-wadding produces evil effects. Rag-pickers and wool-sorters are exposed to mixed dusts, which often contain bacteria and other infectious germs. Bleachers suffer from exposure to chlorine and alkaline vapours. All these dangers may be removed by a rational system of ventilation, suitable to the various exigencies of the various crafts.

The following are short abstracts, partly deduced from the evidence tendered before the commission appointed in 1876 to inquire into the working of the Factory and Workshops Acts, supplemented by the author's personal observations, to show the sanitary evils of the principal British manufacturing industries.

### *Flax.*

According to Dr. C. Pardon, the death-rate from chest affections in the preparing-rooms is painfully high, viz. 31 per 1000; in the heckling-rooms the death-rate is 11·1 per 1000; and amongst the weavers 9 per 1000.

Dust from the flax is the principal cause of the terribly high death-rate, although the children suffer from the dampness of their clothes, caused by the spray which flies from the machines. The dampness brings on bronchial affections.

If a girl gets a card at eighteen years of age, her life is generally terminated at thirty-one years.

The carders generally help to shorten their lives by the immoderate use of stimulants, as they are unfortunately induced to have recourse to them to acquire an artificial strength to counteract the prostration consequent on the unhealthy nature of their employment.

The scutchers are also a very intemperate class; the dust and absence of ventilation induce thirst. The closet arrangements are commonly defective.

### *Cotton.*

From absence of or defective ventilation the air of the weaving rooms is filled with minute particles of china clay, size, and cotton fibres, which is inhaled by the weavers in the ordinary process of breathing, or in the operation of threading the shuttle. The sizing put on the warps consists of china clay; from 50 to 90 per cent. of this material is put on the warps. In some of the weaving-sheds the clothes and hair of the weavers are covered with fine dust. The clay so lightly adheres, that the friction incident to weaving separates it from the cloth.

Mortality statistics show a great and growing excess of lung diseases in cotton factories; the most common are consumption and dyspepsia.

Damp foundations are common, and the closet arrangements are often abominable, both in respect to sanitation and morality.

*Spinning and carding.*—No attempt at ventilation, owing to the desire to keep up a regular high temperature; air contaminated by breathing, cotton fibres, vapour, evaporations from oils, grease, and products of gaseous combustion, besides air in a state of tension, produce lassitude, and increase liability to take colds. Closet arrangements exceedingly defective; if water-closets are used, there are no arrangements for preventing the foul gases being drawn into the workrooms.

*Twisting.*—A deadly employment. The sitting position of the worker, combined with the inhalation of size-impregnated air, brings on rapid consumption.

In many cotton and other factories, where yarn has been spun and doubled for use as thread, before it is completed, it is passed through gas jets to burn off the minute particles and ends which have not been properly twisted in spinning.

The jets of gas are upon the upper part of a machine or frame, which is at a lower level than the face of the worker, who ties the ends that may break; and they are all day long inhaling the heated products of gaseous combustion. The great evil of this process requires no comment.

### *Silk.*

Owing to defective ventilation, the air is impregnated with dust filaments of silk, producing lung diseases. The dressing of waste silk is one of the most nauseous of occupations.

### *Woollen.*

Few of the modern mills have any satisfactory arrangements for ventilation, but in the older mills no attempt whatever is made to sufficiently supply pure air to the workers. The woollen fibres, dust, and absence of ventilation, bad drainage and closet defects, are evils only too commonly met with.

The terrible evil suffered by wool-sorters is not so much a result of the defective sanitation of factories, as of the treatment of the raw wool. The disease is perfidiously propagated by that infinitely small but deadly species of organism, the bacteroids. They measure in width $\frac{1}{8000}$ part of an inch, yet, although so small, their power of reproduction is so enormous, that every single bacterium may produce 16,800,000 others in one day of twenty-four hours. Many eminent *savants* say that these organisms originate all infectious diseases, and are caused by the criminal neglect of sheep and goat-rearers. Instead of the poor animals, after shearing, being comfortably housed in clean pens or stables, they are exposed without any cover to the bitter cold and frost, and become diseased, and the deadly organisms are the result. The infected fleeces are, without any attempt at disinfection, shipped off to the manufactories, where they produce disease and death in the most repulsive form.

The breaking up of woollen rags in shoddy factories is one of the most filthy and unhealthy occupations to be met with; instances have been known where the blood-smeared garments of fallen soldiers have been used for the production of shoddy material. The evils of inhaling dust rising from such materials will be evident.

### *Bleachworks.*

In the clamping and drying departments, the excessively high temperature, together with, in many instances, low, unventilated rooms, render the occupation a very unhealthy one. The position of boilers is often below where the girls work; the temperature of these rooms occasionally reaches 130° Fahr.

### *Open-air Bleachworks.*

The beetling process in open-air bleachworks generates a great deal of sickness, especially chest diseases. The cause of this is the excessive cold draughts to which the works are exposed. The wringing process of the Scotch bleaching works is a very hot and unhealthy one.

### *Calendering Works.*

Owing to absence of or defective ventilation and excessively high temperatures, often 120° Fahr., the drying-rooms are very unhealthy.

### *Dyeworks.*

Dr. Absolon found that young girls were prejudicially affected by working in the hot rooms of dyeworks—causing excessive discharges.

### *File and Grinding Workshops.*

Mr. Septimus Arden stated that there has not been any sanitary improvement of late years in factories, excepting that there is more whitewashing. The file and grinding trade is very injurious, although the fan is coming into general use for carrying away the dust. Many of the workshops are very deficient in ventilation and cubic space.

### *Bookbinding.*

Generally an entire absence of ventilation and deficient light. One witness stated that all they desired was ventilation without draught—naïvely remarking that it was very difficult to know how to ventilate. Another witness gave evidence as follows:—I consider bookbinding very unhealthy. For myself, I have worked in large workshops where the ventilation has been very bad, and where, although it has been bitterly cold outside, the steam has been coming down the windows and the walls, and we have been as it were in an oven, and we have constantly caught cold from coming out of hot air like that into a cold winter's night. This witness was of opinion that bookbinding was unhealthy because of the bad ventilation, and also stated that the inspectors differed as to sanitary remedies.

### *Paper Staining Works.*

Witness stated the most unhealthy part of the occupation was the staining with emerald green. People will insist on having the colour. The air of their works is impregnated with mineral dusts, and generally no attempt at ventilation.

### *Printers' Shops.*

Unhealthy owing to overheat and absence of ventilation. One witness stated succinctly the various sanitary defects as follows:—As a rule compositors are very chilly people; they have to pick up cold metal in all sorts of weather, and the cold lead has the effect of withdrawing the heat from the tips of their fingers; and they are very susceptible to draughts, because they work in their shirt-sleeves close to the windows; and they are frequently very near the gas, which would have the effect, if the windows were open, of causing a draught. The difficulty is to obtain fresh air without draughts.

### *General Evidences as to Sanitary Defects and Consequences.*

Dr. Arlidge of London stated that although the moral character of children has improved, rejections on account of physical inability were nearly 50 per cent. more numerous. He thought the sanitary condition of factories was scarcely looked into, with the exception of the comparatively unimportant matter of whitewashing the walls, a process required to be done once a year.

Mr. R. W. Cole stated that in large factories they are in the habit of putting closets in the workrooms, which sometimes are exceedingly injurious to the health. They emit the most frightful odour, so much so, that I have often felt sickened myself in going through the factories.

Mr. Mundella stated that factories are often in a very bad condition from a sanitary point of view.

### *The Factory and Workshop Act*, 1878.

The following are the principal Sanitary Provisions of the above act:—

A factory and a workshop shall be kept in a cleanly state, and free from any effluvia arising from any drain, privy, or other nuisance.

A factory or workshop shall not be so overcrowded while work is carried on therein, as to be injurious to the workpeople; and shall be ventilated in such a manner as to render harmless as far as is practicable all the gases, vapours, dust, or other impurities generated in the course of the manufacturing process or handicraft carried on therein, that may be injurious to health.

For the purpose of securing the observance of the requirements of this act as to cleanliness in every factory or workshop, all the inside walls of the rooms of a factory and workshop, and all the ceilings or tops of such rooms (whether such walls, ceilings, or tops be plastered or not), and all the passages and staircases of a factory or workshop, if they have not been painted with oil or varnished once at least within seven years, shall be limewashed once at least within every fourteen months, to date from the period when last limewashed; and if they have been so painted or varnished, shall be washed with hot water and soap once at least within every fourteen months, to date from the period when last washed.

As to bakehouse situate in any city, town or place containing, according to the last published census for the time being, a population of more than 5000 persons; all the inside walls of the rooms of such bakehouse shall either be painted with oil, or varnished, or be limewashed, or be partly painted or varnished, and partly limewashed. Where painted with oil or varnished, there shall be three coats of paint or varnish, and the paint or varnish shall be renewed once at least in every seven years, and shall be washed with hot water and soap once at least in every six months.

A bakehouse situate in any city, town or place containing, as before, more than 5000 persons—a place on the same level with the bakehouse, and forming part of the same building, shall not be used as a sleeping-place unless it is constructed as follows, that is to say:—

Unless it is effectually separated from the bakehouse by a partition extending from the floor to the ceiling; and

Unless there be an external glazed window of at least four and a half superficial feet area made to open for ventilation: a fine not exceeding twenty shillings for the first, and five pounds for every subsequent infringement of the foregoing clauses referring to bakehouses.

Every hoist or teagle near to which any person is liable to pass or to be employed, and every wheel, strap, or band directly connected with the steam or water, or other mechanical power, whether in the engine-house or not, and every part of a steam engine and water-wheel shall be securely fenced close to the edge of the wheel-race; and every part of the mill-gearing shall either be securely fenced, or be in such position or of such construction as to be equally safe to every person employed in the factory, as it would be if it were securely fenced; and all fencing shall be constantly maintained in an efficient state, while the parts required to be fenced are in motion or use for the purpose of any manufacturing process. Any vat, pan, or other structure used in any process carried on in a factory, and near to, or over which children or young persons are liable to pass or to be employed, that is so dangerous by reason of its being filled with hot liquid or molten metal, or otherwise as to be likely to be a cause of bodily injury to any child or young person employed in the factory or workshop, shall be securely fenced.

A child shall not be allowed to clean any part of the machinery in a factory while the same is in motion. A young person or woman shall not be allowed to clean such part of the machinery in a factory as mill-gearing, while the same is in motion.

# PART III.

## FACTORY AND WORKSHOP SANITATION.

## CHAPTER I.

### THE SITE AND FOUNDATIONS.

Two considerations generally influence the choice of a site for the construction of a building for the purposes of industry, namely, convenience and economy, and these considerations are certainly paramount; but, when possible, the immediate vicinity and the condition of the subsoil should be examined as to their sanitary character. Both subjects will have a decided effect on the health and vigour of the workpeople, and the question naturally arises whether it is economical to employ unhealthy, weak and emaciated operatives in preference to those who are healthy, vigorous and strong. It will be admitted, *nem. con.*, that the latter alternative is to be desired.

Before the trenches are dug for the foundations the subsoil should be examined as to its physical character, bearing in mind that the hygienic nature of the site of the building is as important as the structural character of its foundation. All soils contain air in their interstices, the percentage of such air varying with the physical and local conditions of the soil.

The percentage of carbonic acid is always very high. The other constituents commonly existing are carburetted hydrogen and various organic substances.

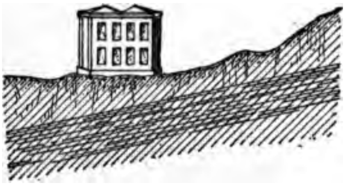
Made soils commonly consist of vegetable and mineral refuse, which, in a state of decomposition, generate fœtid organic vapours; therefore the air of these soils is exceedingly poisonous.

Soils vary in their retention of water in proportion to their density; sand and coarse gravel retaining the greatest, and clay the least.

About 25 per cent. of the rain penetrates into sandstone, 42 per cent. into chalk, and from 60 to 96 per cent. into loose sand. The remaining portion runs off the surface or is evaporated. Independent of the rain, there is a normal subterranean sheet of water which varies in depth from three to a hundred or more feet, according to the conditions and character of the soil. Of course the rainfall increases the height of the subterranean sheet of water, which rises to the surface by capillary attraction. The inclination of the various strata will have a great influence on the hygrometrical condition of the subsoil of the site.

The rain may fall on to the surface a considerable distance from the site, but the inclination of a substratum of impervious material such as rock, will carry it directly under. (See Fig. 3.)

FIG. 3.



If the subsoil water is high the subsoil air will be saturated with moisture, increasing the avidity of the air to absorb deleterious gases.

For a subsoil to be considered hygienically satisfactory as a site, the subterranean sheet of water should never be allowed to ascend to within five feet of the foundations.

To effect this desired result, when the subsoil retains moisture, agricultural drain-pipes should be laid at a depth of say ten feet some time before the foundations are laid, their number proportionate to the density of the soil. They should be laid with a good inclination to the main drain. (See Fig. 4.)

To prevent the moisture and the subsoil vapour from ascending, and being drawn by the suction produced by the heat in the interior of buildings to pollute the air and promote rheumatic disorders, the whole surface of the site should be covered with a layer of some impervious material, such as Portland cement concrete, six inches thick, the surface covered with asphalt.

FIG. 4.

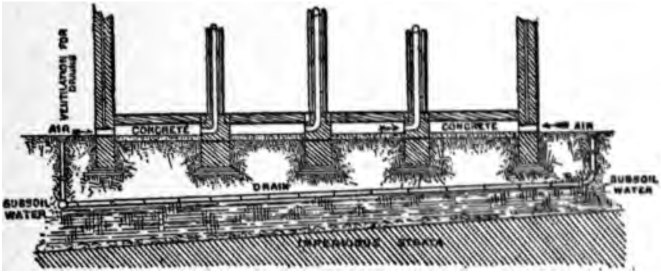
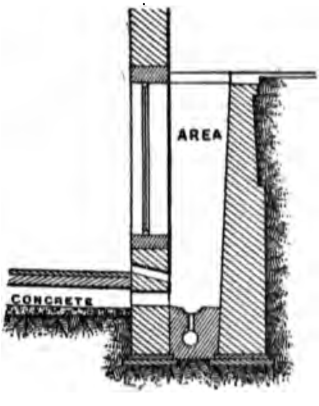


FIG. 5.

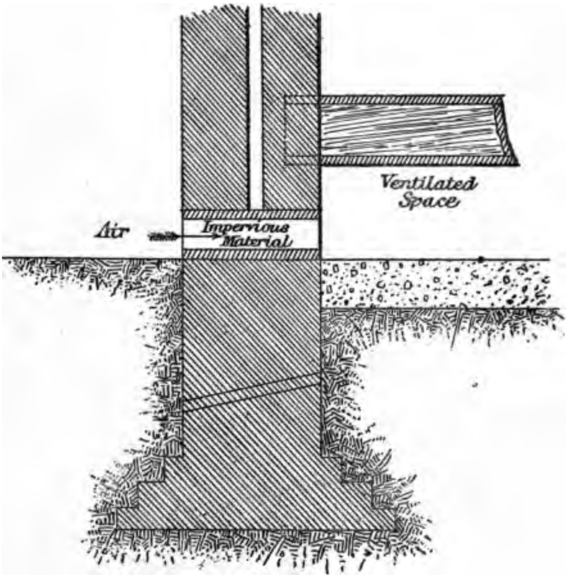


If the building has a basement floor it should have areas arranged along the walls, where possible, with concreted or asphalted surfaces, with a channel formed centrally and properly connected with main drain. (See Fig. 5.)

This arrangement will prevent the unhealthy influence of adjoining undrained subsoils. The ground floors, if constructed of timber, should be at least a foot above the impervious concrete layer, and the space ventilated with perforated bricks or gratings.

For factories or buildings where processes are carried on producing dust, the floors should be constructed of cement, with flags, tiles or asphalt surfaces. If timber flooring is used the floor boards should be grooved and tongued—the joints to be exceedingly close—so as to prevent the dust from accumulating in the space under the floors. Dust should not be allowed to accumulate under the flooring, as the space is so necessary for the escape of any noxious effluvia which might arise from the subsoil. Moreover, the timber forming the flooring, being so well surrounded with air, will not be so liable to that form of timber decay known as dry-rot. (See Fig. 6.)

FIG. 6.

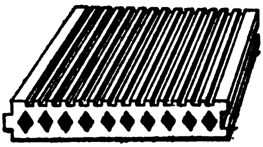


For occupations where there is much moisture or water, the ground floors should be entirely constructed of concrete.

Timber flooring, in processes producing much moisture, absorbs and retains the moisture, thus prolonging the evils of a damp surface—a prolific source of rheumatic disorders and colds.

To prevent the moisture rising by capillary attraction into the walls—a common source of dampness—they should have an impervious damp-proof course laid in the walls under the floor, immediately above the concreted surface. The materials well adapted for this surface are slate, asphalt, slag bricks, or other vitrified material. Stiff and Sons'; and Doulton's damp-proof (Fig 7) course is hollow, and is excellently adapted for the purpose, as well as for ventilating the space between the concrete and the floor. The impervious damp-proof course might act as the base of the cavity in the walls. The moist vapour which might permeate through the outside lining of the walls would condense and trickle down the wall cavities, until it would be intercepted by the damp-proof course, when it would pass away, leaving the inner walls perfectly dry.

Fig. 7.



Made soils are exceedingly dangerous, and, if possible, should never be built upon; but if circumstances necessitate the erection of buildings on such poisonous sites, the arrangements already described will almost, if not entirely, prevent any danger which might arise from the decomposed organic constituents of such soils. Made soils, however, in time become less dangerous, owing to the chemical changes which occur, the organic refuse passing into nitrates, ammonia, hydrocarbons, &c.

The dampness of most existing industrial structures arises either from insanitary subsoils or processes of industry in which water is allowed to fall, or steam permitted to condense on the wall and floor surfaces, to be absorbed and retained by the defective floors and walls. If the floor surface is damp by reason of the inherent moisture of the subsoil, the only way to deal effectually with the evil is to excavate a trench along the external side of the walls, where possible to be formed into an area covered by gratings, the surface of the area to be concreted and channelled and have a good inclination, and be connected with some well-ventilated drain, the water in the subsoil would thus drain into the area channels, rendering the subsoil comparatively dry (see Fig. 5, p. 31). The work of forming the areas or trenches round the walls should be done in the middle of summer, as the drainage of the subsoil in winter might prove dangerous to the stability of the foundations.

If the process of industry is the cause of the dampness, one remedy is to have grids of discharge well distributed over the floors, and connected by well and properly constructed drains to the main sewers, and the water (result of the process of industry) constantly swept towards the grids of discharge.

Another remedy is to provide false flooring formed of timber, iron or brick, perforated with holes to allow the water to pass to the true floor, which should have distributed over its areas channels of discharge leading into properly-formed drains.

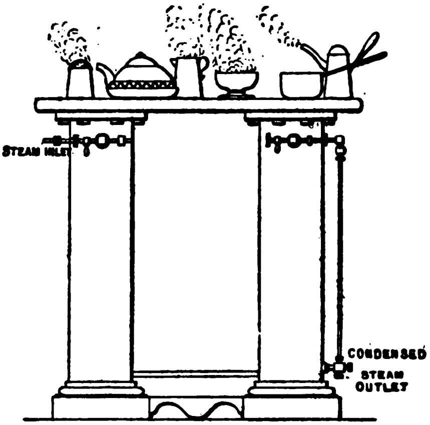
The importance of a dry foundation cannot be over-estimated. Its effect on the health is exceedingly beneficial, and prevents those rheumatic disorders which are the torment of a vast number of those who have to earn their bread by the sweat of their bodies.

# CHAPTER II.

## ROOMS FOR REFRESHMENT.

It is a common practice (although now forbidden by law) for the workpeople to have their meals in the rooms where they are occupied, because in many cases their homes are so far away as to preclude them from having their meals there. When the occupations are free from the production of dust or dirt of any kind there is nothing objectionable in the practice; but where the occupation produces dirt, sometimes of an extremely deleterious nature, the practice of eating in the workrooms cannot be too severely condemned. The contact of the food with so many sources of contamination will eventually have a direful influence on the workpeople.

Fig. 8.



In works of any magnitude, some portion might be set aside in which the workpeople could refresh themselves without fear of dangers from polluted food. If steam is handy, a Bailey's steam-kettle (Fig. 8) might be provided, which would serve the double purpose of heating the room, and for cooking and boiling purposes. A small outlay in this way would prove a great blessing to workpeople living at a distance.

## CHAPTER III.

### CLOSET ARRANGEMENTS.

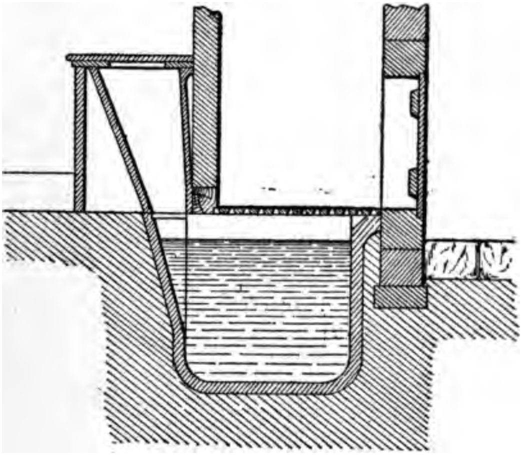
THE importance of a proper closet accommodation, and its effects on the health and morality of the workpeople, especially in mills and workshops where operatives of both sexes are employed, will be acknowledged. Much immorality, vice and disease have been fostered by abominable closet arrangements. In the rural and suburban districts, where the absence of systems of intercepting sewers precludes the use of the water-closet system, earth or ash closets may be used.

The closets should be arranged in convenient positions. The closets for males should be distinctly separate from those for females. Closets on the midden system are extremely unhealthy and should be removed; they not only pollute the atmosphere and thus engender disease, but pollute the subsoil. Closets on the cesspool system are also exceedingly dangerous. The cesspool contaminates the water and air in the subsoil, and often produces disease and death.

A good arrangement and excellently adapted for factories (in extensive use in Burnley) is shown in Fig. 9. The receptacles, which are made of earthenware, will prevent the percolation of the sewage into the subsoil. If desired, the cesspools can be made of concrete six inches thick.

Where coal ashes are plentiful, a good form of closet, and which is extensively used in Lancashire towns, is that

FIG. 9.



shown in Fig. 10; the renewing and emptying of the closet-pails however make this system less applicable to mills and factories, except a certain number of the work-people are deputed to periodically empty the pails, although in a large work there would be no difficulty in arranging with the farmers for the removal of the excreta. Ashes act as deodorisers, and neutralise the too excessive manurial strength of the human fæces.

Fig. 11 represents a closet which has lately been introduced, known as Turner and Robertshaw's dividable closet. The aim of this new arrangement is to separate the liquid urine from the solid excreta. The pail is provided with a perforated false bottom, so that any liquid remaining in the solid excreta may drain off. The liquid urine falls into a pipe A, and after percolating through the charcoal filtering medium B, falls into the drain C, where it may be led either into main sewers, or into an earthenware and covered receiver, to be utilised for manufacturing purposes.

Fig. 10.

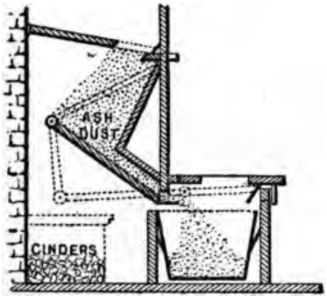
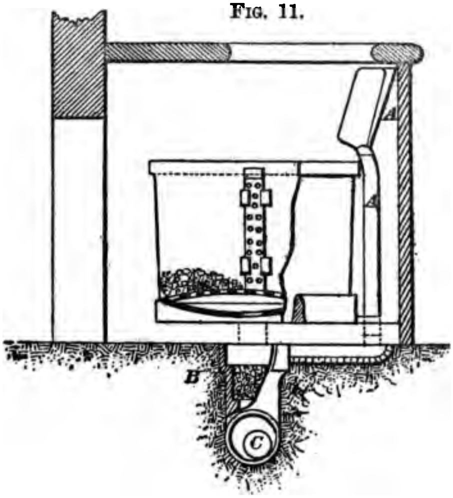
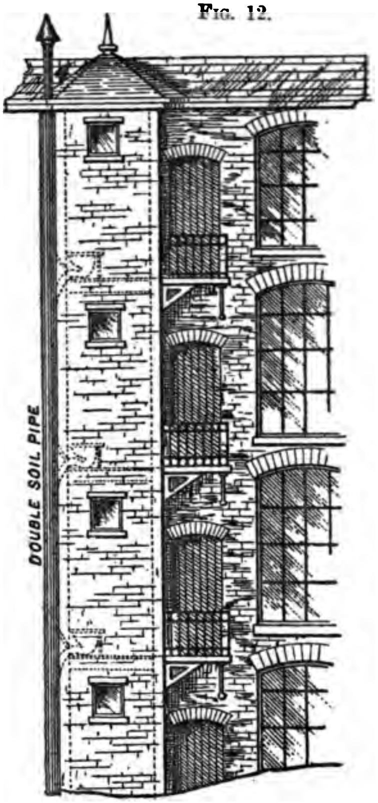


Fig. 11.



For woollen mills, where liquid urine is valuable for fulling purposes, this closet is a great desideratum, and if applied, independently of economical advantages, would remove a dangerous nuisance, at present inseparable from a woollen factory, that is, the collection in open tanks of urine, which is allowed to lie for weeks, a standing danger to health, and which, when disturbed, creates a nauseous effluvium.

Fig. 12.



From the adaptability of water-closets to any storey however high, they are most suitable for large factories. Yet, although so convenient, if not properly arranged, they are a source of great danger to the health, and especially if they form a direct part of the main structure; as the heat of the rooms, if not prevented, will draw the foul gases into the buildings, dangerously polluting the air, often producing some disease of the zymotic class. Water-closets should be arranged for factories in the form of towers, detached from the main structure, to which they are approachable by a landing—cross and efficient ventilation would thus be obtained. This arrangement, which is shown in Fig. 12, would almost entirely prevent the contamination of the air of the factories, a form of pollution so objectionable and dangerous.

For workshops also, where it can be arranged, a passage or open corridor well ventilated should be the means of approach.

As to the closets themselves, the simpler their construction, the better. They must be perfectly inodorous, and efficiently trapped, and the basin should be formed of incorrodible material—earthenware well glazed is the most suitable. The mechanism of the closet should be simple and strong.

All closets with delicate and complicated mechanism must be avoided as totally unsuitable for factories. There should be an ample water supply for flushing from its own cistern, so as to ensure a discharge of sufficient power and volume. The connection with soil-pipe should be direct, although a trap may with advantage be placed midway between it and the water-closet basin.

The D trap and pan form of closet both partake of the character of small cesspools, collecting in their badly-designed basins and traps the fæcal matter which it should be their duty to discharge, besides extravagant and wasteful use of water.

Fig. 13.

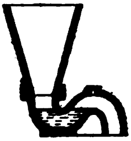
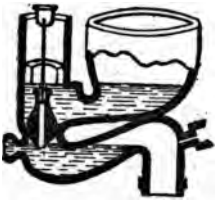


Fig. 14.

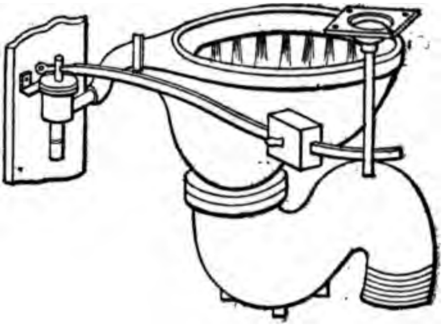


For external use, and where there is an unlimited supply of water, the Hopper closet is well adapted. The water can be regulated by the use of a waste-not contrivance. (See Fig. 13.)

Jennings' earthenware closets have the advantage of incorrodible working parts, and are exceedingly simple, and are especially adapted for workpeople (Fig. 14).

Messrs. Tylor and Sons' closets have many superior qualities, and are especially adapted for offices. In their latest improvements the basin and wash-out are of earthenware, and well shaped, and the circular water-flusher will effect perfect flushing. The closet is supplied with a waste-not regulator valve, in close proximity to seat, a desirable and convenient arrangement (Fig. 15).

Fig. 15.



Tylor and Sons' seat-action, water-waste-preventing closet is well adapted for offices. The action is as follows:—When pressure is applied to the seat, such as the weight of a person, a weighted lever is pressed down, opening the inlet valve of the cistern to flush the basin; on the weight being taken off the seat the valve is immediately closed.

In Dodd's patent closet, the novelty lies in the position of the outlet, which is in front, and not perceptible to the user. It is also well ventilated, and the position of the ventilator will prevent the trap from becoming unseated by syphonic action. The waste-not is arranged in the cistern.

Fig. 16.

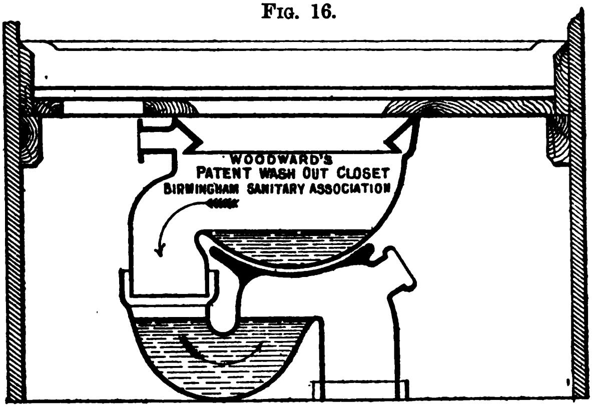


Fig. 16 represents the Woodward patent wash-out closet—an admirable closet in all respects, and well suited for offices and workshops.

Fig. 17.

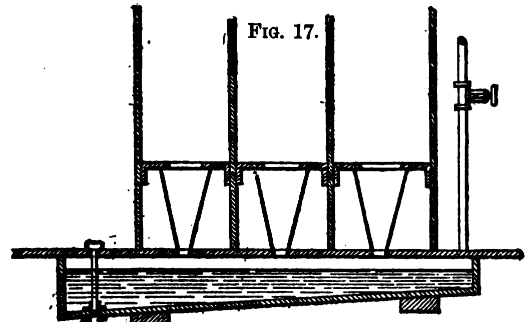
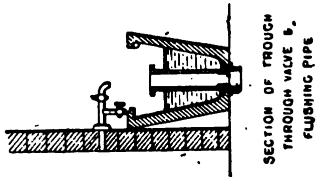


Fig. 17 represents a water-trough closet—a form well suited for factory purposes. It is, however, only applicable to ground floor.

Fig. 18 represents Wilcock's sanitary trough closet, constructed entirely of stoneware, and well adapted for factory use. Of course the success of the trough form of closet greatly depends on the person deputed to periodically flush it.



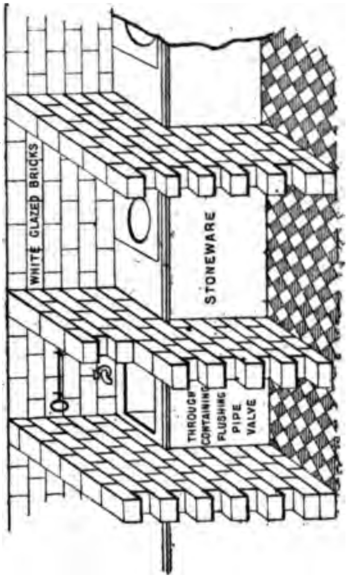


Fig. 18.

There are many other descriptions of closets, which no doubt have merits claiming recognition, but the closets recommended may be considered the standards.

In choosing closets it should be ascertained if they fulfil the foregoing conditions, and if their mechanical working parts are based on sound constructive principles, with the least possibility of wear and tear.

As to flushing, the result will depend primarily upon the force and volume with which the water is discharged, and not upon the length of time it is allowed to run through the closet. Two gallons of water is the acknowledged minimum quantity that should be allowed for flushing, and the supply-pipe should be for each closet 1¼ inches in diameter.

The connection with soil-pipe should be direct. The trap of closet should be ventilated to prevent its being untrapped by syphonic action. If the buildings are erected in climates where the winters are not long or very severe, the soil-pipes should be placed outside the building. In cold northern climates, however, the pipes placed externally are exposed to the action of frost and greater liability to corrosion. They should therefore be placed on the inside wall, with the precautions and improvements suggested further on.

In all cases the soil-pipe should be carried above the roof.

A great improvement to soil-pipes has lately been introduced by Messrs. Warner and Sons, that is, the soil-pipe is lined with block tin, which is far more imperishable in contact with various corrosive influences than lead. Where there are several closets connected with one soil-pipe there is a danger, when two or more closets are simul-

Fig. 19.

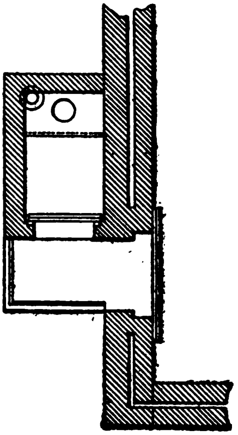
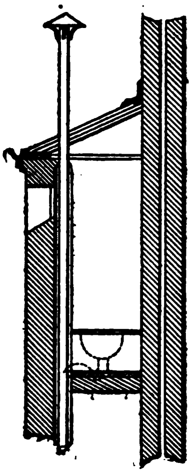


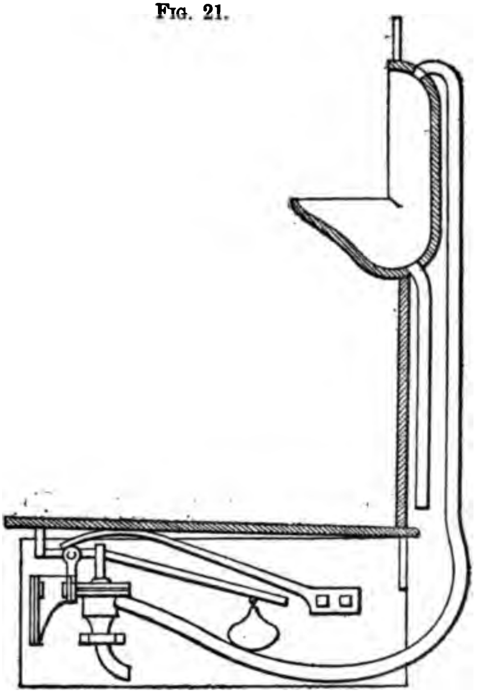
Fig. 20.



taneously in action, of the traps becoming unsyphoned by vacuum or compression.

The author has designed an arrangement of soil-pipes to remedy this evil, and to prevent the danger of gases escaping from the soil-pipe when the latter has become corroded through. The soil-pipe is enclosed in another pipe of larger diameter, the inner, or soil-pipe, being perforated to allow the escape of the compressed gases and to prevent the production of a vacuum, and consequently, syphonic action; and, in case the inner tube should

Fig. 21.



become corroded through by constant contact with the corrosive fæces, no danger would occur, as the gases would pass into the outer air by the current which is constantly passing up the outer tube. (See Figs. 19 and 20.)

The soil-pipe should never be above five inches in diameter, as any increase to this size decreases the flushing power. The pipe should be connected at the foot to a simple trap, which will allow the compressed gases (forced down by the falling fæces) to escape, and prevent the entrance of the sewer gases into the buildings. The following traps are the most suitable for the purpose:—Potts' disconnecting trap, Dodd's, and Stiff's.

Fig. 21 shows a form of urinal, trapped and well adapted for factory use. The urinal is of glazed earthenware, and has a self-acting flushing arrangement, set in motion by the person using the urinal. Where possible, and midway between the trap placed at the foot of the soil-pipe and the sewer, a ventilating pipe should be constructed of six-inch glazed earthenware sewer-pipes. The grating should be so fixed as to prevent the pipe from becoming choked with dirt from the surface. All the traps should be bedded in concrete to preserve the connection with the sewer, which by subsoil settlement is constantly liable to be broken.

## CHAPTER IV.

### LAVATORY ARRANGEMENTS.

In all offices lavatory arrangements should be provided, as a good wash has a stimulating effect on the circulation, and is delightfully refreshing, and especially valuable to those engaged in occupations of a sedentary nature:

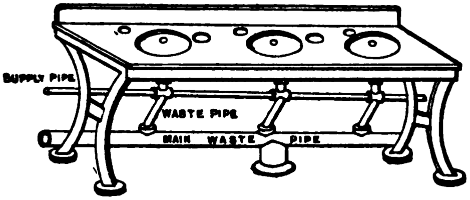
although from defective sewer connections many existing lavatory arrangements are a source of danger to the health.

As a precaution against the entrance of sewer gases, S traps are commonly used; but this form of trap is useless, because if the waste-pipe runs full bore the water in the trap is removed by syphonic action. The best plan is to carry each waste-pipe through the outside wall and let it discharge over a trapped gully or into a well-ventilated trap. A common and serious error is to connect the lavatory discharge-pipe to the soil-pipe.

Jennings' and Tylor and Sons' lavatory basins and apparatus are very perfect.

Fig. 22 represents self-contained lavatory stand, and is a form well adapted for factory purposes.

FIG. 22.



Traps are used to prevent the entrance of sewer gases into buildings.

They should be made of incorrodible material, earthenware or glazed fireclay, and be so designed as to arrest the momentum of the valve discharges as little as possible.

Traps which are square in section and those with very quick angles and bends should not be used.

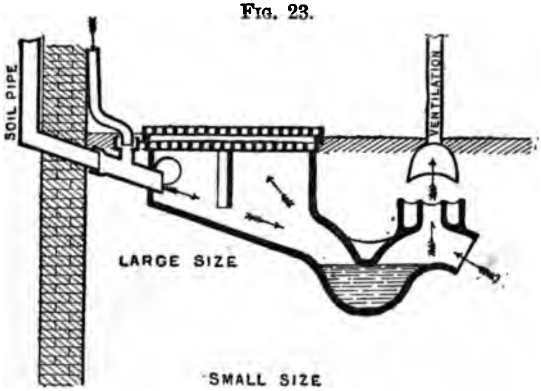
The water-seal should not be too deep, as the solids will not then pass under, but remain on the proximal side, that is, the side nearest the building.

About $1\frac{1}{4}$ inches of a water-seal is considered ample.

The trap should be well ventilated on both sides of seal in order to prevent syphonic action or the trap being forced by sewer gases.

The expansion of sewer gases will sometimes force the traps if they are not ventilated. Expansion of the gases in the main sewer is often produced when hot fluids, such as condensed or dye waters, are allowed to enter the sewers; and sometimes, when sewers are flooded by heavy rainfalls, the gases, suddenly displaced, force the traps.

Fig. 23.



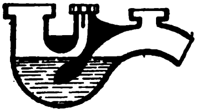


Fig. 24.

Figs. 23 and 24 represent Potts' disconnecting sewer-trap, which has all the requisites of a good sanitary trap, and is well ventilated. Messrs. Stiff and Sons' trap is very simple and efficient, and well adapted to act as a midway trap on a line of private sewers which have a good inclination. It is not so well adapted for sewers with very little fall, on account of the great depth of the seal, although this evil might easily be remedied. (See Fig. 25.)

Dean's patent stench-trap is an admirable contrivance; by a simple device it can easily be cleaned, an advantage which few traps possess. Dodd's patent duplex stench-trap is very simple and efficient. (See Fig. 26.)

FIG. 25.

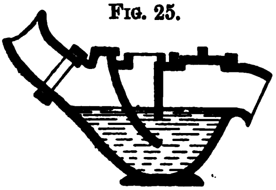
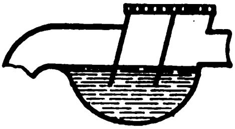


FIG. 26.



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## CHAPTER V.

### BATH ARRANGEMENTS.

CLEANLINESS has such a decisive influence on the health, vigour, and morals of man, that arrangements conducive to it should be provided in all large hives of industry, but especially in those where the occupations produce dust, dirt, &c.

Much disease is certainly produced by the choking-up of the excretory vessels or sweat-glands of the skin and the pollution of the food by contact with dirty hands.

Moreover, the great influence that cleanliness exerts on the morals should in itself be a sufficient incentive for masters to provide for their workpeople ample convenience for washing; so that the workman before leaving the workshop might enjoy a bath, and proceed home to his family thoroughly refreshed, relieving the housewife of much disagreeable work. The improvement of the health and moral tone of the workpeople would certainly in the end prove beneficial to the masters.

The bath and washroom should be arranged in close proximity to the boiler-house, so that the condensed water could be utilised for bathing and washing purposes without entailing extra expense.

A small plunge-bath could be constructed of concrete with puddle-trenches, at a very small cost.

Slipper-baths should be formed of galvanised iron, or the iron should be coated with magnetic oxide or enamel. Slate slabs are also well adapted for the purpose.

Nothing can be superior to the bath fittings supplied by Messrs. Jennings, Tylor and Sons, and Finch and Warner.

A trivial payment by each person using the baths would provide a fund for the cleaning of the baths, providing towels, soap, and other lavatory requisites. But perhaps a better plan would be to make each person provide his own lavatory requisites.

## CHAPTER VI.

### PRIVATE COMMUNICATING SEWERS.

THE arrangement of the private sewer communication with main sewers deserves the most careful consideration, for the health character of the factory or workshop, &c., depends greatly upon its efficiency.

The sewer-pipes should be of fireclay or stoneware, well glazed, sound and perfectly concentric. The connecting joints should be made in cement. In making the joints care should be taken to leave no internal projections of the jointing material. This fault in jointing will arrest the passage of the solids, and their accumulation will eventually choke the sewer-pipes.

The private sewer, where possible, should have an inclination or fall sufficient to ensure for its contents a velocity of not less than three feet and not more than ten feet per second.

The line of private sewer communication should be as direct as possible to the main sewer. Acute angle bends should be avoided; the more obtuse they are the less they retard the flow of sewage. A settlement in a line of sewer-pipes will destroy the connection, so that in subsoil at all liable to settlement it is absolutely necessary, if the system of sewage removal is to be permanently successful, that the sewer-pipes should be embedded in Portland cement concrete. An escape of sewage into the soil is exceedingly dangerous, as by capillary attraction the contamination of the subsoil water may extend to the site of the factories, &c., and if not prevented, the contaminated subsoil air may be drawn into the buildings, disseminating germs of disease and death.

As to the direction of the line of sewer, it should be laid tending to the direction of the flow of the sewage in the main sewer. The immediate connection with the main should be effected in such a way that the direction of the private and main sewer currents should be as nearly as possible identical.

When the main sewer is constructed a correct plan of the private sewers should be made, so that their position can be easily ascertained for future alterations. All such alterations should be correctly marked on the plan.

# CHAPTER VII.

## UTILISATION OF WASTE FROM THE MANUFACTURE OF TEXTILE MATERIALS.

WOOLLEN, greasy rags and other textile wastes are often thrown away and allowed to accumulate in close proximity to factories, until decomposition sets in with the resultant generation of unpleasant effluvia. The rags should never be allowed to accumulate, but be utilised for manurial purposes. Ordinary woollen rags, on account of the large proportion of nitrogen they contain, have a high manurial value.

The Continental *modus operandi* for preparing the rags for the purposes of agriculture is as follows:—The rags are exposed to temperatures varying from 102° to 140° Centigrade, by which they are converted into a reddish tinder, emitting a strong odour of chicory and burnt wool. Thus treated, they lose 10 to 15 per cent. of water, and are also rendered fitter for assimilation by the soil, with a guaranteed strength of 6 to 8 per cent. of nitrogen. According to the Industrie Blätt, 1875, the baked woollen rags sell at 11*s.* per kilo. Almost all descriptions of rags are reducible in a similar manner, and are more or less valuable as manure.

Woollen waste forms an excellent disinfector, absorbing excrementitious matter of any kind. It mixes therewith, readily absorbing the liquid, and rendering the mass easy of carriage.

At one Belgian sugar manufactory the cesspools of the privies are regularly supplied with a certain quantity of woollen residue.

## CHAPTER VIII.

### MILL LODGES OR RESERVOIRS.

MILL reservoirs, from want of proper attention, become in time veritable sloughs of disease. They are often the receptacles of all descriptions of refuse; but the putrid accumulations, except in cases of necessity, are rarely removed; and the stench of the vapours which continually arise from the surface of the water, especially if the condensed water from the steam engine is poured into it, is simply intolerable. The obnoxious vapours pollute the atmosphere, and all the workers are liable to danger by the inhaling of them. If the lodges were properly constructed, the trouble of a periodical removal of the accumulations would be very small.

## CHAPTER IX.

### RESPIRATION.

BEFORE treating on the subject of ventilation, a brief outline of the physiological action of the supply and renewal of pure air for the purification of the blood, will show the vital importance of the subject of ventilation.

Before the food becomes converted into animal power, the chyle which is produced from it by the organs of digestion must be changed into blood, and driven by the heart to all the functions of the body, each function receiving blood-power proportionate to the amount of its work; and the vitality or power of the blood is reflected at once in the quality and quantity of work done. If the blood deteriorates, the work of the various functions shows a corresponding depreciation.

The blood newly formed from the chyle is of a florid red colour. On deteriorating in quality it becomes darker; and when the blood has lost its power of supporting life, it becomes of an almost black colour. The colour of the blood is always a true index of its strength. The renewal of vitality or power to the blood is effected by two processes—the formation of additional chyle from fresh food, and respiration. By the process of respiration the exhausted and powerless blood absorbs oxygen from the inhaled air, and sets free carbonic acid to be driven off in the process of exhalation. The carbonic acid is the effete production of the organic work of the blood. This important interchanging process is the work of the lungs, which consist of an endless ramification of minute capillaries or arteries upon the wonderfully delicate membrane of millions of small air-cells. The blood in its passage through these minute arteries absorbs oxygen from the air contained in the air-cells, and sets free carbonic acid which, by the next respiratory action, is driven off.

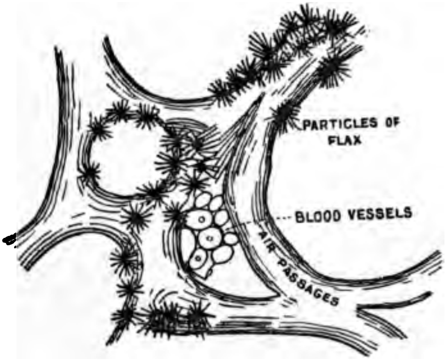
The blood by this process is revivified. The absolute waste power, occasioned by organic work, is made good by the supply of new blood from food. The membrane of the air-cells not only allows the carbonic acid and oxygen to pass through it, but it allows the passage of a large quantity of watery vapour. So marvellous and delicate are the lungs, that although the blood cannot pass through the delicate membrane without actual rupture, yet the membrane of the air-cells presents no obstacle to the watery vapour; and yet how terribly common are the abuses of this wonderfully delicate function.

The blood, as will be seen, is the direct producer and supporter of life; and on its quality depends the character of the life. If defective or deficient food is used, excessive labour done or impure air breathed, the blood will not be renewed or purified, and the health will thereby be rapidly impaired. So necessary is pure atmospheric air to the vitality of blood that its abstraction will eventually produce death.

Besides the capillaries, or blood-vessels and air-cells, the lungs are provided with excreting vessels. Every one will have noticed on a winter's day the steam-like vapour which issues from the mouth and nostrils. This vapour is the moist exhalation driven from the excreting vessels, which constitute one of the waste outlets of the human system. Thus, the air which we expel in breathing is vitiated not alone by the carbonic acid given off by the lungs from the blood, but also by the addition of watery vapour and animal effluvia, and other noxious residuum of the system. It is this residual vitiation which renders the expired air so exceedingly dangerous if reinhaled; besides, the exhaled vapour, if not removed, condenses on the inner walls of buildings, trickling down in fœtid streams. The lungs readily absorb poisonous substances, which are often present in vitiated air. Pure atmospheric air, hygienically perfect, consists of 21 parts of nitrogen, 79 parts of oxygen, and 0·04 parts of carbonic acid. If the above relative quantities are in any way altered, the condition of the blood will proportionately deteriorate; for example, if the air contains more carbonic acid than the normal proportion which exists in pure air, it will be unsuitable to that extent for the purpose of purification, and the blood, and consequently the human system, will suffer to a proportionate extent. Besides, on reflection, it will be seen that the carbonic acid is an index of the amount of animal effluvia present in the air. The process of respiration and blood purification is essentially similar to the ordinary process of combustion, and is attended with the same result, e. g. the generation of heat, and by this process the animal heat is sustained. It is therefore obvious that if the respiratory process is imperfect in any of its conditions, it will be followed by an insufficient generation of heat; therefore the act of breathing impure air produces a low animal temperature. A healthy person breathing pure air has therefore a higher animal temperature, and is consequently less susceptible to extreme changes of temperature than is one inhaling vitiated air. Owing to the wonderfully delicate formation of the lungs, the danger of breathing air impregnated with dust is exceedingly great, the dust clings to the air-passages of the lungs and impedes the passage of the air.

Although the evil effects of breathing impure air are only gradual in their action, they are none the less deadly. About one-fourth of the deaths in Great Britain occur from that fearful and terrible disease, pulmonary consumption, the majority of which can be traced to that most flagrant violation of the laws of nature, e. g. the breathing of dust-laden or impure air. Fig. 27 represents part of a lung (magnified 30 diameters) of a flax-dresser who died at forty years of age.

Fig. 27.



## CHAPTER X.

### PHYSICAL CONDITIONS WHICH AFFECT VENTILATION.

FOR an increase of 1° Fahr. in the temperature of the air, there is a corresponding increase in bulk of $\frac{1}{491}$ part of the volume at 32° Fahr., and a corresponding decrease in weight per volume. Now, assuming the normal temperature of the atmosphere to be 65° Fahr., and the temperature of the air exhaled in the respiratory process to be 98° Fahr., or about the normal temperature of the blood, a striking increase in the temperature and consequent rarefaction of the air will take place in buildings where a large number of persons are present, such as in large factories and workshops. The heated air will therefore rise to the ceiling of the rooms, and hence it follows that, if buildings subject to natural conditions of temperature have outlets arranged near the ceiling, the foul and vitiated air will pass out. If, however, such outlets are absent, the upper stratum of air becomes cooled, and consequently denser and heavier by contact with the ceiling; it therefore descends, and by diffusion contaminates the influx or breathing air.

According to Dr. Tyndall, the heat-absorbing power of gases may be expressed as follows :—

| | |
|---|---|
| Oxygen .. .. .. .. .. .. | 1 |
| Chlorine .. .. .. .. .. .. | 39 |
| Hydrochloric acid .. .. .. .. | 62 |
| Carbonic acid .. .. .. .. .. | 90 |

Now, it will be seen that carbonic acid has a high coefficient of heat-absorption, and it will therefore ascend as soon as exhaled above the line of breathing. Pure air or oxygen has a low coefficient of heat-absorption, and therefore remains at the breathing level; but carbonic acid radiates next in proportion to its power of absorption, so that if there are no outlets of escape at the ceiling it will radiate its heat, and being half as heavy again as air at a similar temperature, will at once descend to pollute the breathing air. These facts therefore point to the necessity of having outlets in buildings (where dust is not produced) near the ceiling.

The amount of carbonic acid in the air is a true index of the amount of the organic vitiation.

The maximum amount of organic vitiation (represented by its index, or carbonic acid) being known, we can then ascertain the quantity of air that should be provided for each person. Now, the average quantity of carbonic acid present in normal atmospheric air is 4 volumes in 10,000, and it is considered by Dr. Parkes and other eminent hygienists that 6 volumes in 10,000 may be allowed without any danger. We have therefore 6 minus 4 volumes, or 2 volumes of carbonic acid the allowable increase as a working limit.

When the amount of carbonic acid in the air is increased by respiration to 7 volumes in 10,000, the smell of the organic matter is perceptible, and becomes very strong when the amount reaches 10 volumes.

The average amount of carbonic acid exhaled by a man of average size is 0·6 or $\frac{6}{10}$ths of a cubic foot per hour, or three cubic feet in five hours; hence it follows that 15,000 cubic feet of pure air will be required in five hours to prevent the quantity of carbonic acid from exceeding 6 volumes in 10,000, or the safe allowable limit of increase: therefore, if 15,000 cubic feet of pure air are required in five hours, 3000 cubic feet per hour will be required for each adult person, to preserve the atmosphere in a healthy condition, exclusive of the air required to dilute the products of gaseous combustion, or to supply oxygen required for fires, gas-lights, &c. Assuming that the products of combustion of gas-lights are led away by independent outlets, instead of contaminating the air; about 100 cubic feet of oxygen will be required per hour to support the combustion of one gas-burner. According to Wolpert, for each cubic foot of gas consumed 1800 cubic feet of air will be required to properly dilute the products of combustion. The oxygen required for the combustion of one pound of coal is 240 cubic feet.

The pressure of the atmosphere on the surface of the earth is generally taken as equal to a column of air of uniform density and temperature five miles in height. This column would be equal to a pressure of 14 lbs. to the square inch, and air would pass into a vacuum with a velocity equal to that which a body would acquire in falling from the height of five miles, or 1339 feet per second. If, on the other hand, the air passed into a room containing air of a higher temperature, and consequently less pressure, the velocity of the falling air would be due to a height which represents the difference of pressure outside and inside. As already explained, for each degree Fahr. of increase of temperature, air is dilated $\frac{1}{491}$ part of its volume. Therefore, the velocity may be ascertained by the following formula:—

The height from the inlet to the outlet multiplied by the difference of the internal and external temperatures, and divided by 491. Example:—Assuming the height from the inlet to the outlet to be 30 feet, and the difference of temperature to be 20° Fahr., the weight of the denser air will produce a velocity of inflowing air $= \frac{30 \times 20}{491}$.

The square root of this result multiplied by 8 will give the velocity in feet per second.

Example:—To ascertain the superficial area of inlets required to supply sufficient air to 30 operatives engaged in a workroom in which the normal temperature is 80° Fahr. Assuming the normal temperature of the external atmosphere to be 40° Fahr., height from inlet to top of outlet shaft 30 feet—

$$\frac{30 \times 40}{491} = \frac{1200}{491} = 2{\cdot}45$$

$$\sqrt{2{\cdot}45} = 1{\cdot}57 \times 8 = 12{\cdot}56 \text{ cubic feet per second,}$$

or 45·216 cubic feet per hour will pass through an orifice one foot square.

The quantity of air required = 30 (the number of operatives) multiplied by 3000 (the quantity of air required for each person per hour), or 90,000 cubic feet. Therefore $\frac{90{\cdot}000}{45{\cdot}216}$ will equal the superficial area of aperture, or total sum of apertures required, viz. two square feet of inlet areas.

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## CHAPTER XI.

### VENTILATION.

All the civilised nations of antiquity have left some relic evidence that they appreciated the importance of ventilation.

The Egyptians used a peculiar kind of fan-sail to produce currents of air.

The Romans, in their magnificent baths and amphitheatres, have left practical examples of this important branch of sanitation.

The exquisite Hall of the Baths, a relic of the splendid architecture of the Moors, is ventilated by means of conical openings, a form exceedingly well adapted for the purpose.

The famous traveller, Marco Polo, found evidence that the Chinese in very early times well understood the method of ventilating buildings.

The science of ventilation has long engaged the attention of philosophers and constructors.

Agricola appears to have suggested the rarefaction of air by heat, in order to produce circulation.

Keslar has shown that many of the Italian stoves indicate considerable knowledge of the laws of ventilation.

At the commencement of the seventeenth century Cardinal Polignac investigated this subject, and in the 'Mécanique du Feu' (1715) published several tables relating to the subject of ventilation.

In the course of 'Experimental Philosophy,' published in 1744, Dr. Desaguliers wrote several articles on the subject; and Dr. Franklin, in his Philosophical and Miscellaneous Papers, describes a system of window-sash ventilation.

In 1818 the Marquis de Chabannes wrote a pamphlet recommending the use of gas-lights for the purpose of withdrawing the vitiated air. About this time, Sir Humphry Davy made careful investigations as to the best means of ventilating the House of Commons.

Faraday wrote some articles on the subject in the 'Quarterly Journal of Science.'

General Sablukoff practically applied in 1835 the Archimedean screw for ventilating purposes. (See Föster's 'Allgemeine Bauzeitung.')

Clanelin first suggested the method of dividing the air into small streams to obviate the draughts. ('Dictionnaire de Physique.')

In 1841 M. Péclet directed the attention of the French Government to the desirability of ventilating the schools, and in the following year M. Felix Leblanc published an exceedingly interesting and valuable series of investigations into the changes in atmospheric air, induced by breathing and by other organic exhalations. ('Annales de Chimie et de Physique,' vol. v. page 223.)

In a pamphlet on ventilation, published in 1855, Dr. Neill Arnott proposed the form of valve known by his name.

Up to within a few years back the science of ventilation was all but ignored in England.

In France, however, the subject has not only been thoroughly investigated but successfully applied, especially to domestic dwellings. Thanks to the important investigations of M. Charles de Freycinet, Ingénieur des Mines, particular attention has been directed to its application to industrial structures. After an exhaustive examination of the various industries in England, he came to the conclusion that the subject was very little understood and rarely applied. In France, however, he found that various ingenious ventilating arrangements had been devised. He ascertained that, for manufactures producing deleterious gases, such as coke-ovens, lime-kilns, chemical works, lead paint works, the most efficacious system of removing the gases for ventilation is to use the exhaustive power of very high chimney stacks. He found that at Rennes, in the mills for grinding bark belonging to M. Leroux, exhaust fans were used for collecting the dust.

At Oisel M. Fauquet had devised a very remarkable arrangement for the ventilation of his cotton mills. The points aimed at were, the removal of impurities, the production of a certain degree of humidity, and the maintenance of a uniform temperature. To prevent variations in the temperature of the roofing, due to changes in the weather, the surface of the arches forming the soffit or ceiling was built up with ordinary glass bottles. The necks and bodies being placed alternately and perpendicular to the surfaces of the arches, the empty spaces were then filled with mortar. The bottles were then drawn out leaving a light honeycombed shell, this was covered by a coating of plaster, thus constituting a mattress of air confined in a multitude of cells. Two large fans, placed in a subway, renew the air and expel the impurities. A fan is placed near the carding engines to expel the dust. The circulation of the air is obtained by means of a system of conduits arranged under the flooring and opening into gridded orifices. To produce the necessary degree of humidity, cold water is injected into the subway by means of a spray.

At Antwerp, for the phosphoric match works, ventilation is obtained by means of a large central chimney, which receives the gases from the boiler furnaces, a large underground flue runs along the opposite sides of each building and opens into the chimney, thus leading away the vitiated air and deleterious vapours. At some of the factories of Nantes and Chateauroux, the air is drawn by fans from the outside, in winter the air being passed round heating stoves; the dust-impregnated and vitiated air is led into exhaust chimneys over the roof.

In the spinning-rooms at the woollen factory of MM. Hauzem, Gerard & Co., of Verviers, fans exhaust the air from two ends, the fresh air being admitted through several openings in the floorings. The combing machines, which are in separate buildings, are also provided with fans. The woollen stuffs are spread on a grid covering a large casing closed up at the sides, a fan powerfully exhausts the air from the inside of this casing, while a current of hot air is led against the ceiling of the building. By this ingenious plan the workmen are entirely free from the unwholesome atmosphere that is generally present where the vapours are allowed to be disengaged freely and to accumulate in the interior of the mill. These applications are evidence that the teachings of General Morin have not been lost upon the French manufactures.

In England very little progress has been made in the development of systems of ventilation suited to the exigencies of various industries, and the methods of ventilation which have been applied are more or less defective. Of course the success of any system of ventilation depends to a great extent upon the persons it is intended to benefit. From the foolish opposition of many people to the entry of pure air into buildings, many systems of ventilation which possessed great merit have been pronounced failures. It is hoped that the extension of sanitary knowledge will eventually prove to the public how important and necessary the proper supply of pure air is.

Before further considering the practical application of ventilation, it will be as well to examine the physical qualities of various walling materials, as they have a decided bearing on the success of any method for the supply of air, and upon the hygienic character of an industrial structure. Walling materials are more or less porous and absorbent, and consequently allow diffusion of air in direct proportion to their density. Lime and sandstones are far more porous than granites and other igneous rocks. Hand-made bricks are very porous, while machine-made bricks, owing to the great pressure applied in their manufacture, are considerably less so.

The following materials are very porous:—All sandstones and other aqueous rocks, hand-made bricks and mortar. Materials that are only moderately porous:—All limestones, terra-cotta, hard-burnt machine-made bricks and concrete. Materials that may be considered non-porous, or impervious and non-absorbent:—Vitrified stoneware, slag bricks, glass, asphalt, slate, and most of the igneous rocks.

Walls built of brick and mortar, therefore, allow both water and air to permeate through them, and even if plastered and papered with unglazed paper, air and water will pass through to some extent. Of course, the air passes through the walls more rapidly than water, air being 770 times lighter than water. This slight diffusion will assist ventilation, but the evil of dampness is the drawback. To prevent this, all external walls should be built with a cavity or air-space at least two inches wide, a system of walling which has other merits from a fire-resisting point of view (see page 33). Damp-proof courses or hollow vitrified bricks must also be placed at the floor level to prevent the ascension of the moisture by capillary attraction from the soil, and also under the eaves to prevent the descension of moisture from the roof, and for the same purpose damp-proof courses should be placed at the junction of the slates with the chimneys or stacks which rise above the roofs. For further remarks on this subject, see page 33.

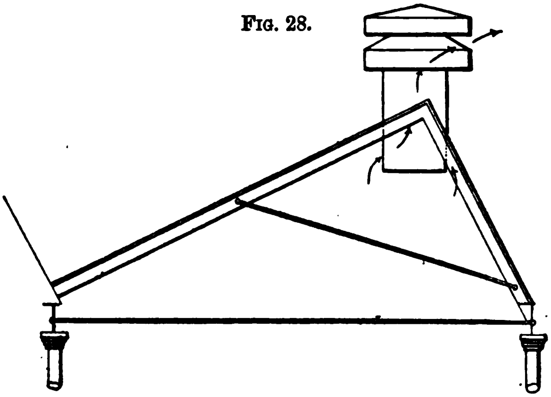
Ventilation, to be successful, should be arranged to suit the various exigencies of the process of manufacture it is intended for. In the dust-producing processes, such as sorting, cleaning, &c., the temperature and degree of moisture, although not high, should be uniform; as quick as the dust is produced it should be removed by a system of downward ventilation, this would in most instances prevent the dust from ascending to the breathing level. The channels for leading away the vitiated air and dust should be arranged below the floor, traversing the principal footways and having branch connections with each dust-producing machine. The exhaust pressure should be produced by fans, placed at the connections with the outlet upcasts. The sides of the channels may be formed of tinplate, boards, or cast iron, and should be covered with gratings, easily removable for cleaning purposes. By this arrangement the dust would at once be drawn into the channels The various inlet openings should be distributed along the external walls. The inlet air should be heated to the temperature suited to the exigency of the process, and properly distributed throughout the rooms. The dust and other materials which obstruct the exhaust channels should be regularly removed. For the purpose of exhaust, Schiele's fans are the best. (See page 87.) The outlet upcasts should be carried above the roof, and where convenient should be connected with the chimneys. Where the floors are of such construction as not to allow the channels to be placed below the floor level, the vitiated and dust-impregnated air must be led off by the upward system of ventilation. The channels to be arranged under the ceiling. The inlets must be arranged at the floor level along the walls.

The importance of removing the dust as soon as produced will be obvious. If not removed, it will eventually be deposited on the dress of the workers or be inhaled.

Where the rooms are of one storey, or when they are top storeys, other systems of ventilation are available.

In the weaving-sheds, with the roofs constructed on what is known as the saw-tooth principle (which, by the way, is a most excellent form of roof, on sanitary grounds), the outlets may be arranged in the roof (see Fig. 28), and

FIG. 28.



the air may be extracted either by fans or by an exhaust produced by wind currents. The outlet channels or ducts should be arranged along the under side of the ridge of roofing, the sides of the ducts should be perforated with holes at regular distances along the whole length of the weaving-sheds. To ensure exhaust pressure along the whole length of the outlet ducts the whole area of the perforations must not exceed the sectional area of the outlet duct multiplied by the number of outlet exhausters. Of course, in the system of ventilation with fan-extractors of great power, the outlets in the ducts may be more numerous.

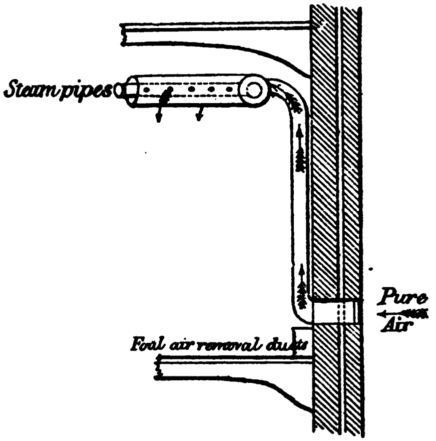
Those processes not producing much dust, but requiring a high degree of temperature and moisture, such as carding and spinning, are in many instances productive of as much unhealthiness as the dust-producing processes. In the majority of instances there is not the slightest provision for ventilation, for fear of lowering the temperature. Mere air inlets in the walls are the only provision for ventilation attempted, with the obvious result that the workpeople object to the influx of cold air, producing, as it does, disagreeable and dangerous draughts, ever evidence of defective ventilation. The operatives consequently stop up the inlet openings.

Owing to the expansion and rarefaction of air at high temperatures varying from 90° to 100° Fahr., a greater volume of air must enter the lungs to produce the same oxygenation as that of air at the normal temperature; again, elevated temperatures increase the quantity of insensible perspiration, and therefore increase the poisonous qualities of vitiated air; so that, if there is no provision for a supply of pure air, the danger of inhaling the vitiated air is considerably greater.

Any person observing the spinners and carders of a cotton mill will have noticed their pallid and unhealthy appearance. To successfully apply ventilation to these processes the air must be allowed to enter at a temperature very little below that of the rooms. In cotton spinning-rooms the air must also have a certain degree of moisture, as the electrical condition of dry air acts detrimentally on the cotton threads, making them brittle.

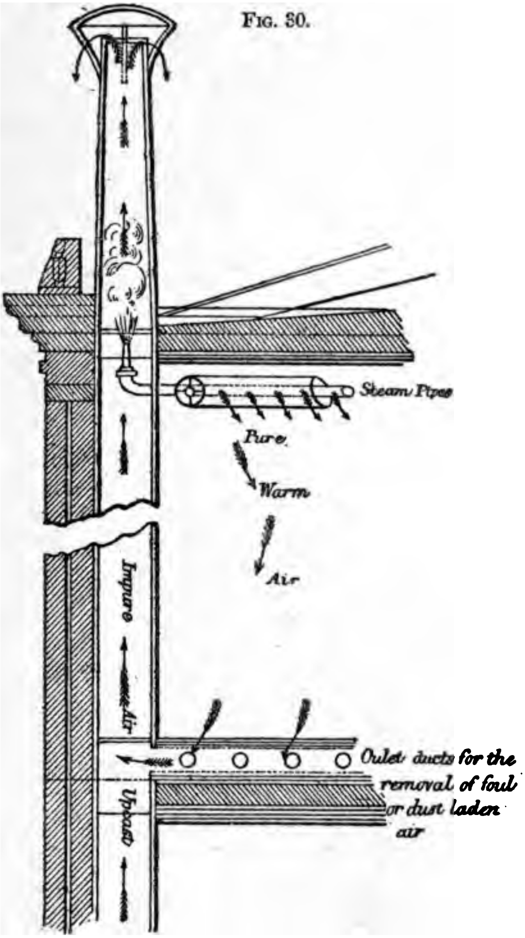
The almost universal system of heating rooms for textile manufacturing processes is by means of steam. The simplest plan, therefore, is to allow the air to enter a cased box containing coils of steam pipes, placed vertically, and by allowing condensed water to slowly trickle down the pipes; the air could thus be heated and moistened to any degree. The size and number of the coils must be proportioned to the number of the workpeople. The outlets, channels or ducts, which are arranged along the walls, and perforated with orifices, should be connected with the upcast outlet shafts. The exhaust might be produced by fans, exhaust cowls, or, if steam is available, by fixing a jet at the summit of the exhaust shaft, an effective exhaust pressure would be produced. Another plan is to encase all the steam pipes with tin casings, with small perforations, and allow the air to enter them (see Figs. 29 and 30). The upcast shafts should be of a capacity to extract the air from every storey, and at the summit they might be made to form a pleasing architectural feature to the generally monotonous appearance of factories.

FIG. 29.



The upcast outlet shafts can be constructed of brick or

FIG. 30.



masonry, or, if these materials are inconvenient for use, tinplate or wrought-iron sheets may be used. If the upcast shafts at their summit are near the boiler chimney, its extracting power might be utilised by connecting them together; a light flap-valve should be placed at the junction of the upcast connection with chimney to prevent back draught.

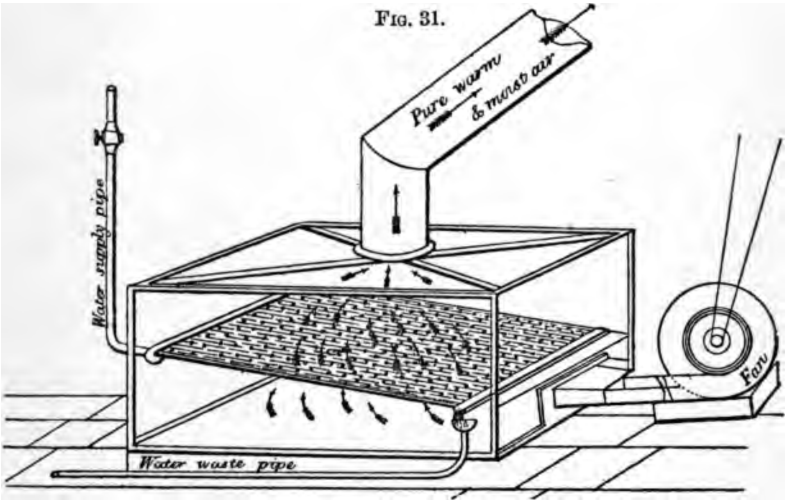
When fans, steam-jets or chimneys are not available for the production of exhaust pressure, extracting ventilators may be fixed on the summit of the shafts (see page 82).

Several ingenious arrangements have of late years been devised to supply air of any degree of temperature and hygrometry.

The following is a description of the most rational of the devices:—

Some years ago an apparatus was completed by Messrs. Nézeraux and Garlandat for supplying air of any desired

FIG. 31.



temperature and moisture. M. Nézeraux originated the idea, and M. Garlandat assisted him to practically perfect it.

The apparatus (see Fig. 31) consists of a casing or compartment divided into two horizontal portions by a perforated plate, either of metal or some other material. The air is driven by a fan into the lower portion, and passes through the numerous perforations in the plate. Above the plate, water of any desired temperature is introduced by a pipe provided with regulating tap. The water enters uniformly upon the plate by a distributing pipe. The plate is slightly inclined in such a way that the depth of the water shall not exceed certain limits. Ice, or phenic acid, &c., may be substituted for water, according to the temperature or application desired.

The pressure exerted by the propelled air suffices to maintain the water on the plate, which, after having passed over the plate and absorbed the heat from, or given off its heat to the air which penetrates it, finally reaches the other pipe, by which it issues, to be reutilised for other purposes. The air escapes by a tube, to be distributed where wanted. The air after leaving the apparatus is found to be healthfully fresh, and hygienically perfect.

A process strikingly similar to that of Messrs. Nézeraux and Garlandat's has lately been patented and introduced by Mr. Lacy, of Howarth's Buildings, Manchester.

The apparatus (see Fig. 32) consists of A, a fan by which air is drawn down the trunk B from the open air, or when hot air is required, closing a damper in the said trunk and taking the warm air through the pipe C from the boiler-house or other suitable place, forcing it into the first compartment D, which contains a coil of copper, which is used in connection with the coil H in the upper compartment for either steam in winter or cold water in summer. Thus any desired temperature can be attained. The air is forced from the compartment D through a perforated plate F, on which a film of hot or cold water is maintained, supplied by the pipes E where humidity is required, and afterwards the air passes off through the pipes L and is distributed where required.

Water of a temperature below 65° Fahr. will supply cool, dry air. A higher temperature of the water will thoroughly saturate the air, which may be further warmed by the admission of steam, whilst ice placed in the upper compartment will cool the air to almost any degree.

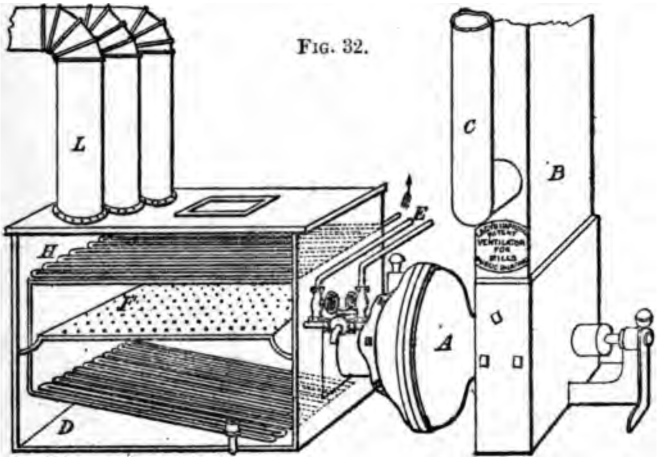


FIG. 32.

This system is well adapted for textile factories and workshops.

A novel system of ventilation has been patented by Professor Wilkinson, of Baltimore, U.S., and is becoming extensively applied (see Fig. 33). A is the ingress shaft, B is the subway, C exhaust shaft, D exhaust chamber, E steam generator, F stove in exhaust chamber, G smoke pipe up chimney. The arrows indicate the direction of the air.

According to Professor Wilkinson's experiments, a properly constructed subway will transmit and discharge continuously and regularly a given volume of air at the temperature of the earth through which the subway penetrates, or at about 50° Fahr., whether the air is admitted to the subway at 100° Fahr. above, or 26° Fahr. below, zero.

Professor Wilkinson lays great importance on the construction of the subway.

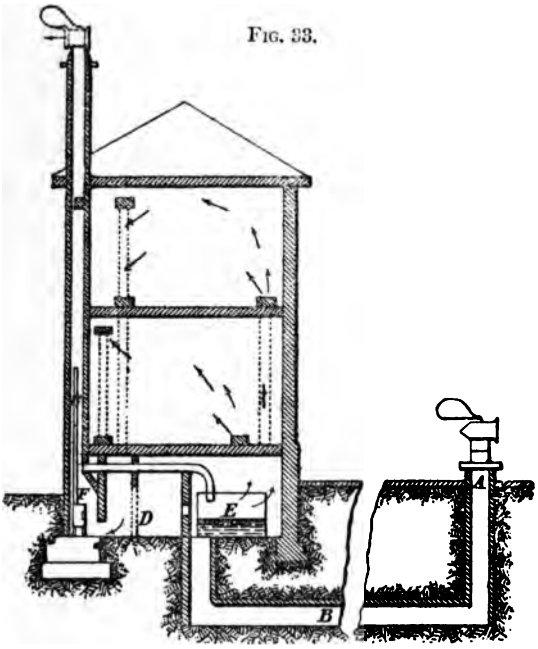


FIG. 33.

The duct must have a clay bottom, and must be tunnel-shaped in section. If the substratum is not of clay, the surface of the subway must be artificially surfaced with it, in order that the deodorising and antiseptic qualities of the clay may thus be utilised.

The friction of the air against the moist sides of the subway frees it from solid impurities, dust, &c. The air is found to be refreshingly cool in summer, and is less exposed to the electrical variations of the atmosphere—a point of importance to dairymen and distillers, or wherever the process of fermentation is carried on. In one experiment, in the month of January, when the external temperature was 26° below zero, the air delivered by the subway was found to be 40° Fahr. above zero, or an increase of 66°; many other experiments produced the same result.

### *Processes producing Vapours.*

In the gassing-rooms, dyeworks, bleaching works, &c., great volumes of steam and vapour are constantly given off, replacing and expelling the air—a great source of evil and discomfort to the workpeople. Moreover, during the time the rooms are filled with dense vapours, many accidents have happened; the movement of the workpeople is impeded, and consequently very little work is done.

Fixing louvres on the roof is the only remedy at present adopted for the removal of the vapours. Louvres, if properly constructed, are to a certain extent useful as outlets for air, but for the rapid removal of the vapours they are almost useless.

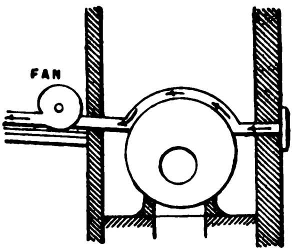
Over each beck, vat, or other receptacle producing vapour or steam, a powerful extractor should be placed—a powerful fan is the most suitable—arranged to be put in motion or regulated as soon as the steam and vapour are generated; by this means the vapours would be dispelled and removed instantly, and as soon as they were removed the fan could be stopped.

A system adopted by a German for the ventilation of his dyehouse has proved a decided success. Over each beck he has erected wooden chimneys, in which gas flames are constantly burning, producing an effective exhaust. He has also utilised the heat radiation of the boiler to warm the incoming air, with the necessary precautions to prevent the air from becoming charged with smoke-dust.

For driving the warm air into the rooms he utilises Roots' blowers.

When the dyehouses are on the ground floor, this method is easily applicable, only it would be unwise to use wood frames, owing to danger from fire—wrought-iron plates are more suitable. When the workroom is in close proximity to the boiler, by a simple arrangement, that of covering the boiler with hollow bricks or wrought-iron sheeting (see Fig. 34), the radiated heat could be utilised to heat the air. Care must be taken that the coal-dust and sulphur usually emanating from the stoke-hole shall not pollute the air.

FIG. 34.



*Workshop Ventilation.*

According to the evidence given to the Parliamentary Commission, workshops generally are totally deficient of any ventilation. In some instances mere air inlets are provided, but these the workmen stop up, because of the draught they cause. The majority of workshops are, indeed, hot-beds of disease.

In some of the large workshops steam pipes are employed for the purpose of warming, and where this system exists the arrangement described in pages 99 and 100 will be found available. For those occupations in which dust is produced, and where a fan can be employed, the arrangement should be similar to that described on page 65, viz. outlet ducts or channels should be laid below the floor, where possible, and connected to each duct-producing machine. If the outlet ducts cannot be arranged below the floor, they should be arranged along the walls immediately under the ceiling. If a fan is not available, the ducts should be led to outlet and upcast shafts to create an exhaust, and if steam is available a steam jet may be used (see Fig. 30, page 69); or if steam is not available, a gas jet burning in the outlet shafts will be found to produce an effective exhaust. If neither of these methods are available, an extractor ventilator may be used, although for occupations producing dust, the methods of exhaust the most effectual are induced currents produced by heat, steam, or the fan. Extracting ventilators dependent on the wind currents for producing exhaust are often, in calm weather, worse than useless. In those occupations where dust is not produced, and sufficient outlet ducts are provided leading to the outlet shafts, an extractor ventilator or cowl may be used to produce the necessary exhaust pressure, as a permanent exhaust pressure is not imperative except the occupations produce dust, &c. The cowls or extractors fixed on the summit of the upcast shaft should have outlets equal in area to the sectional area of the upcast shaft, so as to allow free passage to the air with a minimum amount of friction; and for the same reason air outlet ducts, channels, &c., should have as few angles as possible, as they produce eddies and create unnecessary friction.

When the method of heating workshops is by open fires, the air for ventilating purposes should be led to cavities arranged in the piers forming the sides of the fireplaces, as described for office ventilation, and from the heating cavities should be uniformly distributed. If there is no other arrangement for heating workshops, the air may be heated by gas stoves, placed in as central a position as possible (see heating arrangements).

While on the subject of workshop ventilation, a few remarks may with advantage be made respecting the ventilation and drainage of stabling.

It is acknowledged by some of the most eminent experts of the veterinary art, that many of the most dangerous diseases to which horses are subject, owe their origin to insanitary stabling.

Air inlets for ventilation at least one foot square should be provided for each horse. Tobin's air inlet ventilators (see Fig. 43, page 82) are well suited for the purpose. For outlets, Kite's ventilators (Fig. 46, page 83) are very suitable, one should be placed over every stall.

The subsoil of the site of the stable should be well drained, and the walls rendered impervious to moisture in the manner described on page 32.

The paving of the stabling should be of some impervious material, with as few joints as possible, in order to prevent the retention of the solid or liquid manure, which if allowed to remain for a length of time, will decompose, and become a source of discomfort and danger to the horses. When the horses are in the fields the manure on decomposition assimiltaes with the soil, and in that state of course it is harmless to the horses. The surface of the stables should be paved with two-inch flags laid upon a layer of concrete, the joints cemented, and the surface grooved and laid with a good slope, in order to accelerate the removal of the liquid manure.

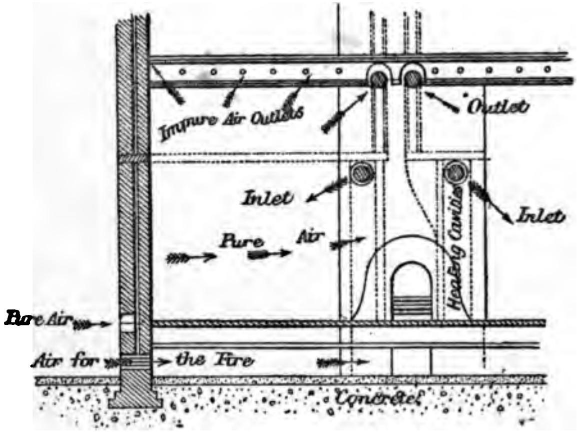
### *Office Ventilation.*

In few instances is the importance of ventilation more apparent than in that of offices, owing to the sedentary labour of the regular occupants; and defective ventilation, in this instance, followed, as it is, by drowsiness, headaches, and only too often pulmonary consumption, is certainly adverse to economical office management.

When the method of heating the office is by means of the uneconomical but certainly cosy open fire, the air should be led from the outside by means of cavities in the walls, or by special ducts to cavities formed in the piers of the fireplace (see Fig. 36), and be allowed to enter the office at a height of about five feet from the floor. The inlet openings should be covered with iron or zinc valves, arranged so as to be closed or opened at pleasure.

For carrying away the vitiated air, the cornice should be constructed so as to form an outlet duct, and perforated at intervals, and leading either to the chimney flue, or, better still, to a separate outlet shaft built alongside the chimney flue—the latter, by its heat, will induce an upward current (see Fig. 36); or the air may be led to an independent shaft surmounted with an extractor ventilator or cowl. On referring to the arrangement shown in Fig. 36, it will be seen that the fire is supplied with air from an independent source. This arrangement will prevent the fire from abstracting the oxygen from the rooms, and will further prevent draughts from under the doors, which chill the feet to a disagreeable and sometimes dangerous extent. It may as well be pointed out that doorways should not be placed on the same side of the room as the fireplace, especially if the fire has not an independent air supply, otherwise, when the doors are

Fig. 36.



suddenly opened, the cold air rushing in and across the fire will draw the heated gases from the fire into the rooms. Where offices are in proximity to the factories, the most desirable arrangement of heating is by steam, obtained from the factory boilers; the air may be heated, and perfect ventilation secured, by the system described on page 75.

### *Warehouse Ventilation.*

For rooms utilised entirely for the purpose of storage, the inlets for air should be arranged along the external walls at the floor level, and the outlets fixed at the highest point of the ceiling or roof. Ordinary louvres, if properly constructed, will be suitable for covering the outlet openings. If the outlets and inlets are sufficiently numerous, a good circulation will be constantly produced, as even in storage rooms where there is nobody regularly at work, and therefore no organic combustion and generation of heat, the temperature of the rooms will vary considerably from that of the external atmosphere, and the difference of temperature consequently produces circulation of the air. Of course, where warehouses are constantly occupied by workpeople, similar arrangements to those suggested for workshops will be necessary.

## CHAPTER XII.

## VENTILATING APPLIANCES.

### *Inlets.*

THE provision most generally adopted for allowing the entrance of air is to make window-sashes moveable. The diagrams (Figs. 37, 38, and 39) show the various systems; the arrows indicate the direction of the air currents which generally produce most disagreeable draughts. The arrangements are more or less imperfect. Fig. 39 is the best of the bad arrangements. A modification intended to lessen the defects of window-opening arrangements has been introduced with some success by Dr. Bird. His

Fig. 37.

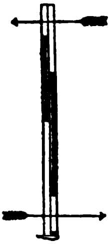


Fig. 3.

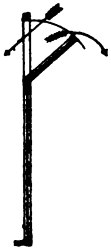
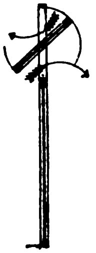


Fig. 39.



method is to perforate the lower sashes with holes, opposite to which is placed a diverting board, which diverts the direction of the air currents upwards. (See Fig. 40.)

Fig. 40.

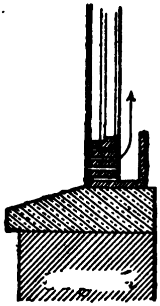
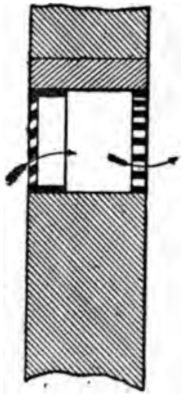


Fig. 41.



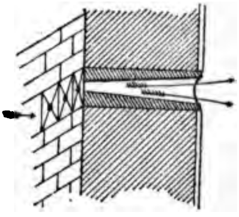
The position of the inlets should be carefully considered in order to ensure a supply of pure air. They should never be placed in positions near drains, sewer ventilators, cesspools, stagnant pools of water, waste or manure heaps.

A simple form of inlet opening commonly used is shown in Fig. 41, consisting of an opening, covered with a grating of iron or a perforated sheet of zinc. Generally the perforations of the gratings and the zinc are too small and numerous and soon become choked. If iron is used, they gradually, from corrosive influences, rust away. All iron inlet gratings should either be often and well painted or be coated with magnetic oxide by Bower's or Barff's process. The perforations should never be less than half an inch square.

Perforated bricks are often used—the perforations are commonly too small, and their length too great. The bricks should never be thicker than two inches, and should be made of fine blue clay, or other vitrified material.

Inlet bricks having conical perforations have lately been introduced. This excellent form of inlet was extensively used by the Moors of Granada. By the slight diffusion of the air in passing through the gradually widening perforations, the velocity of the air is interrupted, and entering the room in small streams, well diffused, its entrance is not much felt. (See Fig. 42.)

FIG. 42.



The introduction of this excellent form of inlet opening is due to a Mr. Ellison, of Leeds.

A system was introduced some years ago by a Mr. Tobin, also of Leeds (although Mr. Tobin's claim to have originated the idea is disputed). The principle of this system is to allow the air to enter rooms by means of vertical pipes of a certain height, say six or eight feet, so that the cold air ascends to the ceiling and falls in cascades, becoming diffused and warmer before it reaches the breathing level. The objection to this system is that the incoming air, in falling, meets the ascending exhaled air, and thus is partially rendered impure before it reaches the breathing level. (See Fig. 43.)

FIG. 43.

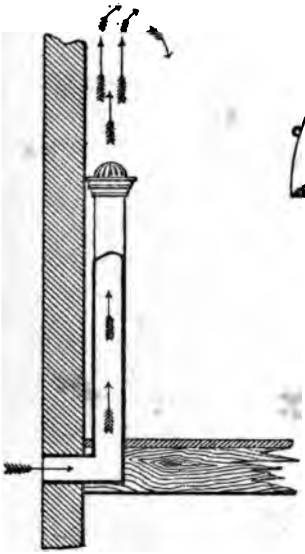


FIG. 44.

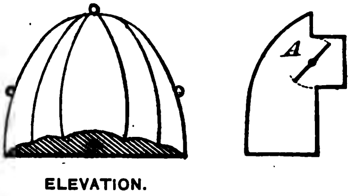
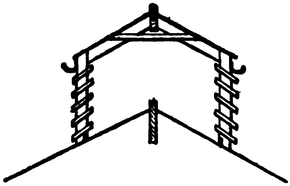


FIG. 45.



### *Outlets.*

Fig. 44 shows Weaver's simple and excellent form of outlet, suitable for offices and small workshops. The valve A, Fig. 44, prevents the danger of back draught. The material is metallic, but it should be galvanised. Outlets of this description should be fixed in all exhaust flues as a double precaution against back draughts.

### *Extracting Cowls and Louvres.*

To be perfect, extracting cowls should possess the following qualities:—They should offer unobstructed passage for the efflux of the air; they should totally prevent the entrance of rain and wind currents; they should have no moveable parts, and be as simple in form as the principle of their action will allow.

They should divert the direction of wind currents in such a way as to create syphonic action, and produce an exhaust pressure in the upcast.

The various descriptions of extracting cowls which are before the public may be divided into two classes, viz. fixed and moveable.

### *Fixed.*

The simplest form is that of the louvre (see Fig. 45), although as generally constructed this form is very defective, and allows the entrance of both rain and wind currents. The manufacture of louvres should never be entrusted to ordinary artisans.

FIG. 46.

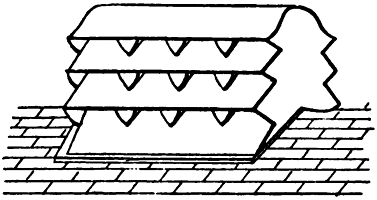


FIG. 47.

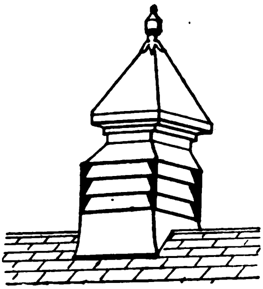


Fig. 46 is a great improvement on the ordinary form of louvre, and is a patent of Mr. Kite, of London. Wind currents passing through the vanes create a powerful exhaust. They are perfectly weather-tight and can be fitted in any position required, and are exceedingly cheap.

They are provided with solid or perforated wire valves, which can be opened and shut at pleasure by a cord and balance weight; they are formed of galvanised wrought-iron or zinc.

Weaver's Extractor (Fig. 47). The action of this ventilator is similar to the above; it is very perfect in its action and thoroughly weather-tight.

Hill and Hey's Excelsior Syphon Exhaust is similar in action to Weaver's and is a very good form.

FIG. 48.

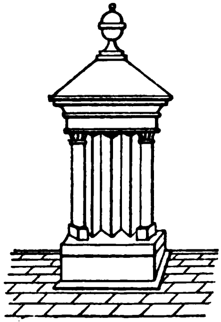
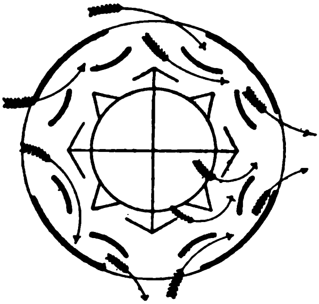


FIG. 49.



Boyle's Air Pump Extractor is shown in Figs. 48 and 49. The wind currents follow the direction shown by the arrows and create an effective exhaust. They are perfectly weather-tight and are formed of galvanised wrought-iron or zinc.

These extractors are the most perfect in principle and in action, and are deservedly becoming universally appreciated.

*Moveable.*

The old-fashioned cowl is shown in Fig. 50. By the action of the wind, the opening of the cowl is turned away from the direction of the movement of the wind. On days when the wind currents are constantly changing in their direction, sudden and violent down-draughts accompanied with rain occur at every variation, and the noise made by the ever-moving cowls is anything but pleasant.

Moreover, these cowls are rarely balanced to such a nicety as to be moved, except by strong wind currents, so that the opening of the cowl is often dead-set against wind currents of moderate velocity, and continuous down-draughts are the result. In time the spindles and bearings become rusted together, thus allowing to wind and rain unobstructed entrance.

FIG. 50.

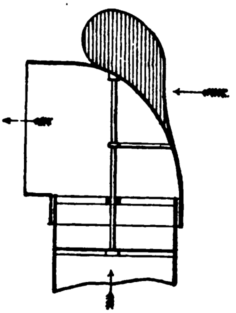
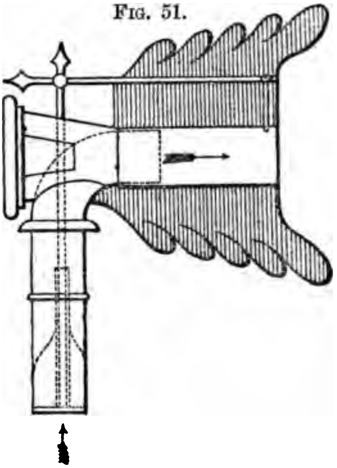


FIG. 51.

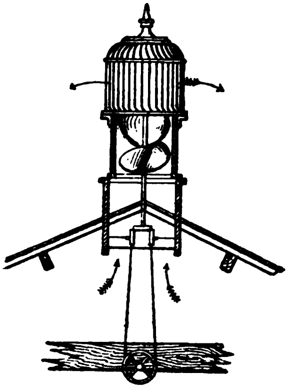


Banner's Cowl (see Fig. 51). The action is somewhat similar to the old-fashioned cowls just described; the larger end of a funnel-shaped tube placed horizontally, is always directed towards the wind, and a current of air passing in there is pressed forward through the annular space between two cylinders, and when it reaches the end of the inner one expands all round it, and in passing out at the smaller end it creates a vacuum round the point of the inner cylinders, inducing an exhaust in the upcast.

Banner's cowl is an improvement on the old-fashioned form, but it is very liable to get out of order.

Howarth's Archimedean Screw Cowl (see Fig. 52). The principle of this well-known cowl consists of a vertical hood provided with vanes, overlapped to prevent the entrance of rain. The wind currents act upon the vanes in the same way as they act on the sails of a windmill, and the hood revolves, and along with it a screw, which at each revolution pumps out a certain quantity of air and thus produces a vacuum and induces a current.

FIG. 52.



The bearings of the spindle carrying the screw and hood are of incorrodible metal—a decided advantage. This form of cowl is not, however, so effectual as some of the fixed ones, and it is more liable to get out of repair. Moreover, when the weather is calm and sultry, a time when ventilation is most desired, the hoods are quiescent, and there is not the same area of unimpeded opening as there is in the fixed cowls.

Where motive power is available these screw cowls should be made to revolve by driving bands; when thus propelled they are excellent extractors, and have been applied in this manner with great success for the purpose of extracting and expelling steam, sulphurous gases, dirt, and other emanations.

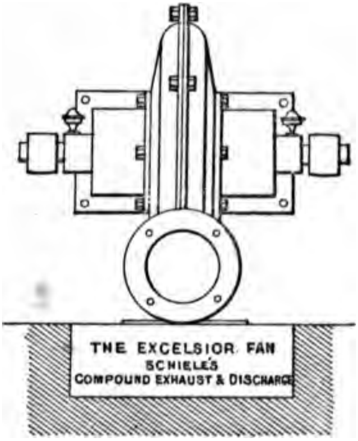
Where motive power is available the most effective manner of extracting and expelling air, dirt, &c., is to use well-balanced and properly constructed fans.

Ventilating cowls are suitable for one-storeyed buildings and warehouses where the occupation and manufacture are not attended with the production of dust, but are, when alone and not propelled, unsuitable for the purpose of ventilating large manufactories producing dust, &c.; they, however, may prove excellent auxiliaries to the use of the fan when placed at the summit of the upcast.

## VENTILATING FANS.

The most perfect form of fan for the purposes of ventilation is that invented by Mr. Schiele, and known by his name. This fan (see Fig. 53) is simple in construction, cheap, strong, and safe, noiseless in its action, and not liable to get out of repair. On each side of the centre, or intake of the fan, cast-iron elbows are attached, provided with flanges for the attachment of ventilating ducts. The air chamber round the tips of the vanes provides a free and quick exit for the particles of the dust, fluff, &c., which are drawn into the fan, and there is consequently no fouling, which has always been a hindrance to the use of fans for ventilating purposes. The fans can be placed in any position in relation to their work, and the elbows can be placed at angles to suit any position. The fan is equally effective for driving or exhausting air, and as

FIG. 53.



the two principles are combined, it may, if necessary, be used as both at the same time.

TABLE OF SCHIELE'S COMPOUND VENTILATING AND EXHAUSTING FAN.

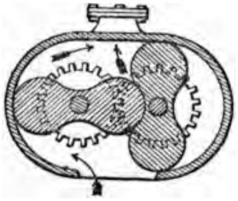
| Size. | Diameter of Discharge Pipe. | Cubic Feet of Air per Minute. | Price. |
|---|---|---|---|
| | inch. | | £ s. |
| 0 | 4½ | 600 | 6 10 |
| 1 | 6 | 1,000 | 8 10 |
| 1A | 8 | 2,500 | 13 10 |
| 2 | 10 | 4,000 | 18 10 |
| 3 | 11 | 8,000 | 29 0 |
| 4 | 18 | 20,000 | 52 0 |
| 5 | 24 | 40,000 | 85 0 |

### *Roots' Patent Blower.*

Although this excellent appliance is more particularly adapted for the purpose of producing a positive blast, nevertheless, it has some points of superiority over the fan. The Roots' Blower operates by a regular displacement of air, measuring and forcing forward a definite quantity at each revolution; no power is wasted upon air that is not used.

It is massive and is noiseless in action, not liable to get out of repair, requires very few changes of motion to produce an effective exhaust (300 revolutions per minute is all that is requisite to produce an exhaust equal to fan velocity of 1000 revolutions with the same diameter of

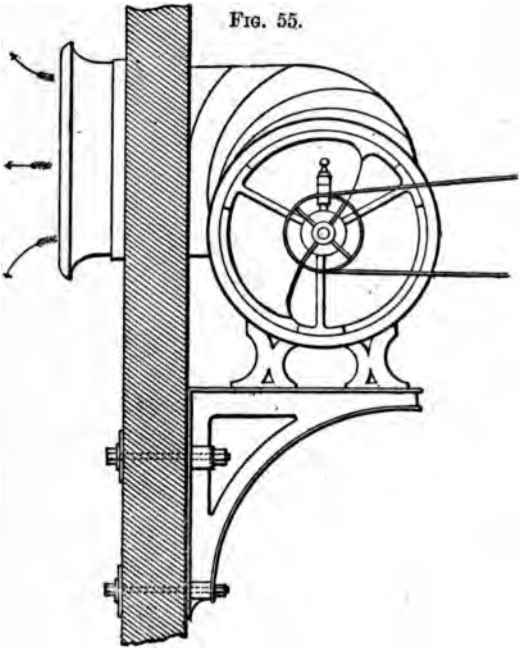
FIG. 54.



outlet). Roots' Blower has been used very successfully for the purposes of ventilation. (See Fig. 54.)

Fig. 55 represents Mr. Howarth's adaptation of his Archimedean screw as a fan; from the shape of the vanes,

FIG. 55.



fouling cannot occur, and the principle of the fan for its purpose is philosophically perfect, and certainly deserves wide recognition.

## CHAPTER XIII.

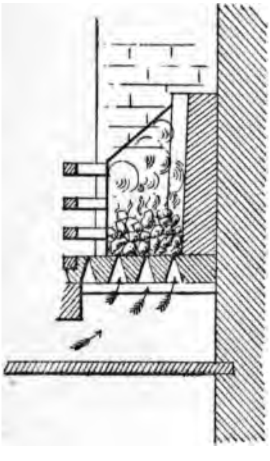
### HEATING ARRANGEMENTS.

### *Coal Fires.*

It is astonishing, considering the attention paid to the subject of warming by Drs. Franklin and Arnott, Count Rumford, and other distinguished physicists, that no general improvement is manifest in the construction of coal fireplaces.

The point that should be aimed at in the construction of a fireplace is, that it shall radiate its heat as nearly as possible uniformly. The laws of reflection of heat and light are the same, viz. the angle of incidence is equal to the angle of reflection; and as radii originating from the focus of a parabola and falling on its sides are reflected back parallel to its axis, therefore the plan of the fireback should be of that form.

Fig. 56.



As soot decreases radiation, it should not be allowed to accumulate on the fireback. The intensity of heat decreases as the square root of the distance from the point of production; therefore the fireplace should project as far as practicable into the rooms.

Fireclay is the most suitable material for the fireback. This material should also be used for forming the basket or bottom of the firegrate for supporting the coals; the basket may be perforated with holes if desired. Fig. 56

shows such an arrangement of fireback and basket, which, by heating the air to an intense degree before it enters the fire, will produce, as near as possible, perfect combustion.

If the room has ample provision for ventilation, the fireplace should be supplied with air by a separate flue from the outside. This will prevent the abstraction by the fire of the pure air from causing disagreeable draughts to the feet; where, however, no provision for ventilation is made, other than the fireplace, the fire should not have separate provision for its supply of air, but be allowed to abstract its oxygen from the rooms, and thus induce circulation, and consequently prevent stagnation of the air.

As already pointed out, door openings should not be formed in the same walls as the fireplace; when the door is suddenly opened, the cold air rushing in and whisking across the fireplace will extract the smoke from the flue into the room.

For an ordinary office fire, 36 superficial inches of chimney area is ample. Large chimney flues promote the formation of smoke by their cooling influence on the inflammable gases.

The chimney flues should be carried higher than the ridge, because the direction of the outside currents has a great influence upon the draught. The flues should be formed of earthenware pipes glazed so as to minimise their friction. They should be so constructed as to offer the least possible obstruction to the passage of the products of combustion. Chimney terminals should be so designed as to assist the chimney draught, making the wind currents subordinate to that purpose, and also preventing down draughts. (See Figs. 57 and 58.)

FIG. 57.

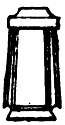
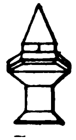
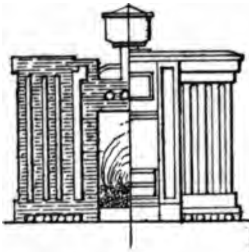


FIG. 58.



Figs. 59, 60, and 61 represent an arrangement of heating invented by Mr. Snell, and is admirably adapted for heating small workshops and offices. It consists of the ordinary fireplace enclosed with hot water chambers, which are traversed by tubular heating vessels; the air for ventilation is brought from the exterior and made to circulate through the pipes, where it becomes heated. The cavity which connects the fire with the chimney flue is composed of two or more flue-tubes, which are also surrounded with water; all the various water-spaces are connected together and a complete circulation is secured. One of the principal advantages of this system of heating air is the fact that as long as the water chambers are continually filled with water, there is no danger of the air becoming burnt; of course the water chambers are so arranged as to preclude any chance of danger of explosion.

FIG. 59.



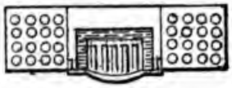
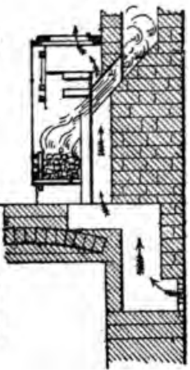


FIG. 60.

FIG. 61.

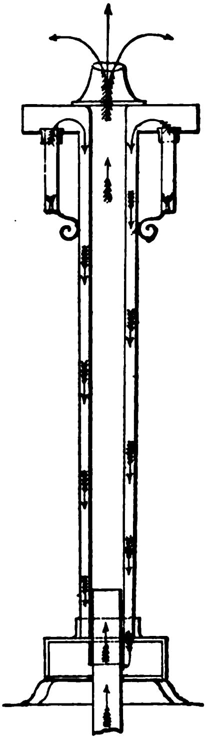


*Gas Heating Stoves.*

Those systems of heating by gas, which allow the products of combustion to pollute the air, are all pernicious, and should be avoided.

Gas heating arrangements, to be safe and healthy, should have independent outlets for the products of combustion; and they should be formed of highly refractory material such as fireclay or asbestos; if they are formed of iron, the metal when highly heated gives off a decidedly injurious effluvia, producing lassitude, headaches, &c. Lately several fatalities have been traced to this effluvia. A novel form of gas stove has lately been invented by Mr. Ritchie of London. (See Fig. 62.)

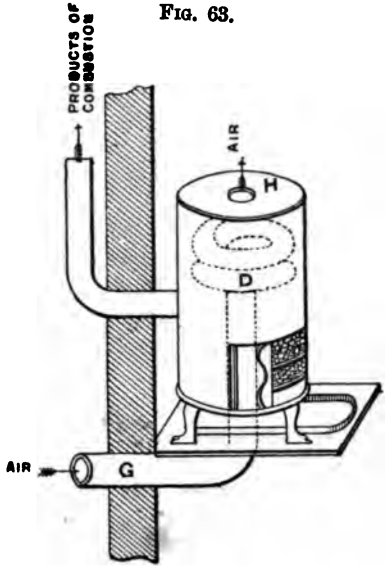
FIG. 62.



The apparatus consists of a pillar-like column supporting gas burners; the pillar has an opening at both ends, the lower opening connected with a receptacle, the upper one opening into the room; from the pillar-like column a projection receives the glass chimney: on igniting the gas the products of combustion ascend into the projection and descend the outer column and issue through the opening at its foot into a receptacle. As the vapours descend the column they become cooled, and are condensed passing down into the receptacle at its foot; this is said to entirely deprive the vapours of their noxious qualities; the products of combustion afterwards pass up the centre of the tube and are led away by a funnel to the outside air; or by simply connecting the opening at the lower end of the tube to a fresh air supply pipe, the fresh air may become agreeably warmed before entering the room.

Mr. George's Calorigen or Gas Stove (see Fig. 63), although not economical, is a very simple contrivance. The body of the stove is of thin rolled iron, and contains a coil D of wrought-iron tubing open at the top H; fresh air enters from without by a pipe G; the products of combustion may go up the chimney in the ordinary way. By slight modifications the above can be made suitable either for coal or steam. This stove is becoming extensively used in France.

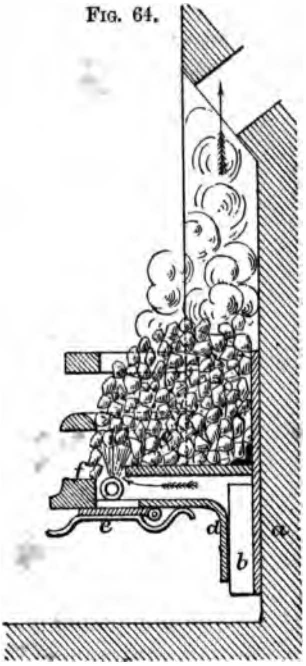
FIG. 63.



If the stove is formed of sheet iron, it should be coated with a silicate solution; this will partially prevent the escape of the noxious emanations through the sheet iron; or a better plan would be to construct the sides of the stove with thin fireclay slabs, tied together by a light wrought-iron framework.

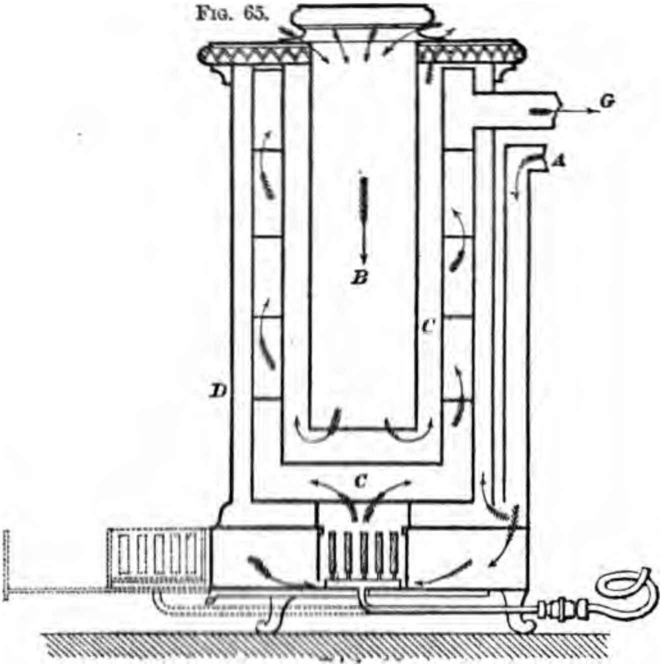
Dr. Siemens, F.R.S., who has been so successful in the application of heat to metallurgical purposes, has lately invented, and generously given to the public, a method of heating by gas, excellent in many respects. (See Fig. 64.)

FIG. 64.



The iron plate *c* is riveted to a stout copper plate *a* facing the back of the fire-grate, and extending five inches above and below the point of junction. The plate stops short about one inch behind the lowest bar of the grate in order to make room for a half-inch gas-pipe *f*, which is perforated with a zigzag line of gas holes for the escape of the gas passing along its upper surface. The pipe rests upon a lower plate *d*, which is bent downward towards the back so as to provide a passage one inch wide between the two plates; a trap-door upheld by a spring is provided for the discharge of the ashes falling into the channel. The vertical part of the passage is traversed by a strip of sheet copper *b*, about four inches deep, bent in and out like a lady's frill, and riveted to the copper back piece—copper being an excellent conductor of heat, and this piece being at least three-fourths of an inch thick, carries the heat from the back of the grate to the frill piece; an air current is thereby set up, which, traversing the horizontal flue, impinges the gas flames and thereby increases their brilliancy. Dr. Siemens has used this arrangement for heating his office, and although it was difficult with a coal fire to keep up the normal temperature of 60° Fahr. during cold weather, this temperature is easily maintained with the gas grate described. The question of relative economy is not yet settled.

FIG. 65.



Another excellent form of gas stove has lately been introduced by Dr. Adams of Glasgow (see Fig. 65). The gas is allowed to enter through burners or cylinders of plumbago, which become incandescent; the products of combustion do not pass up a single smooth flue as is ordinarily the case in gas stoves, but circulate through a series of cells enclosing the chamber of pure air to be warmed. On referring to Fig. 65 representing the arrangement, the circuit of the heated gases is shown by arrows passing into the chimney A. The pure air entering the stove from above to be warmed, first passes down the wide central tube B, then up the narrower middle tube C, escaping by the outlet holes in the top of the stove; another stream of air enters the pipe D at the back of the stove, and after being warmed in a chamber surrounding the fire, passes upwards by the outer shell and escapes at the top. The dotted portion of the figure shows the arrangement for preventing explosions.

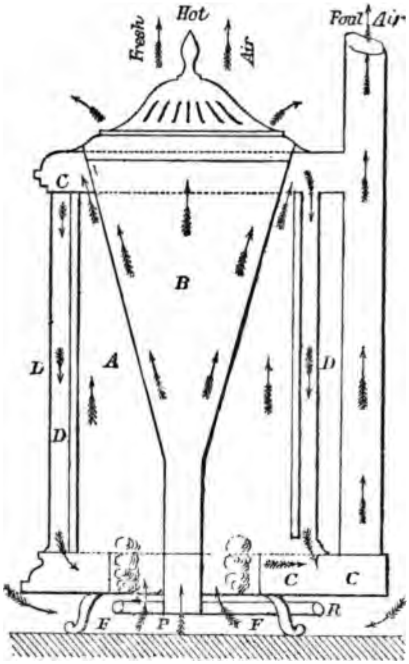
When it is desired to light the stove, the whole furnace is drawn out of its chamber on a sliding-tray or drawer, and until that is done the gas cannot issue from the burners; the act of drawing out the furnace permits a large supply of fresh air to enter the furnace-chamber, so that the gas jets can only be ignited openly in the unconfined air of the apartment, where it is no more liable to an explosion than an ordinary gaselier.

Fig. 66 represents an excellent form of stove invented by Dr. Bond, F.C.S., and known as the Euthermic Ventilating Gas Stove.

The stove consists, in its essential parts, of an iron cylinder A, within which is fixed a metal cone B, the upper and broader margin of which is attached in an airtight manner to the upper part of the stove, whilst the lower and smaller aperture is connected by a tube P with the outer air; around the cylinder a series of tubes D D in the form of columns are fixed, the upper ends of which communicate by means of an annular chamber C with the space between the cylinder and the cone, and the lower ends open into a smaller chamber which surrounds the base of the cylinder.

From this chamber an outlet flue proceeds, which is also connected by a branch near the top of the stove with the upper annular chamber.

FIG. 66.



In this upper branch-tube is a throttle-valve, by means of which the way through it can be closed. This flue may be carried directly into the outer air, or, which is a preferable arrangement, into an unused chimney flue, closed at the bottom to prevent reflux into the room.

At the base of the lower annular chamber is a ring of gas burners F, arranged in such a way as to be easily and safely ignited.

Directly the gas is lighted the metal cone becomes warmed, and a strong upward current of fresh air from the inlet is established through it. This air becomes warmed partly by contact with the surface of the cone, and partly by the heat radiated from it, and escapes into the room through the open mouth of the cone, or through the interstices of the loose cover which is adapted to it. A constant current of warm air thus passes out of the stove, the temperature of which may be regulated with the greatest ease; the inlet of the cone may be supplied with fresh air by connecting it with the outer air, by means of a pipe passing through the nearest outer wall of the room, or through the floor or ceiling: as a heater this stove is decidedly effective and economical.

Where steam or water is the medium used for heating the offices or workshops, the most perfect arrangement is to allow the fresh air to enter boxed-off coils of the steam or hot water, where it will, by passing round the pipes, become agreeably warmed, and may be allowed to enter the room without producing any draught. This arrangement of combined warming and ventilation was suggested by the author in his articles on Hygiene applied to Factories,* and it is certainly the most rational and perfect system that could be desired. Lately Messrs. Weeks & Co., Ventilating Engineers, Chelsea, have introduced a very similar arrangement, which they call the Hydro-Caloric Coil (see Fig. 67). The principle of this coil is, that the external air is admitted through pipes, the external surfaces of which are heated by hot water. Another adaptation of this principle, known as the Hydro-Caloric Battery, is shown in Fig. 68. Such is the efficacy of this arrangement that it has been shown by experiments, that with the external temperature at 50°, and the water in the apparatus at 144°, one of these coils will admit per minute 22½ cubic feet of fresh air at a temperature of 116°, or the amount of 1350 cubic feet per hour at the temperature of 116°. By simply regulating the apparatus any desired temperature can be attained:—

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* Vide 'L'Ingenieur Universel,' 1880.

TABULATED RESULTS OF EXPERIMENTS WITH WEEKS' HYDRO-CALORIC COIL.

| Temperature of External Air. | Temperature of Water in Apparatus. | No. of Cubic Feet of Fresh Warm Air drawn in per Minute. | No. of Cubic Feet of Fresh Warm Air drawn in per Hour. | Temperature at which Air enters Room. |
|---|---|---|---|---|
| 48° | 120° | 15 | 900 | 90° |
| 48° | 128° | 19½ | 1170 | 98° |
| 48° | 136° | 20½ | 1230 | 109° |
| 48° | 142° | 21½ | 1290 | 114° |
| 48° | 144° | 22½ | 1350 | 116° |
| 48° | 148° | 23 | 1380 | 117° |

In factories and large workshops heating by steam surpasses all other methods, and is the most economical. Moreover, the exhaust steam from the engine, after ascending through the heating-pipes, may be utilised for exhausting the vitiated air. (See Fig. 30, page 69.)

The system of steam or hot-water coils should be arranged opposite each inlet of fresh air as described, and where the air is required to be moistened, the arrangement shown in Fig. 67 should be used, which consists of a water-pipe terminated by a rose, which allows water to fall and moisten the ascending heated air.

Safety and stop valves should be arranged on the line of steam pipes (these valves by a simple arrangement can be utilised for fire extinction; 1½-inch branch pipes should also be fixed at the foot of all coils to let out the condensed water. If condensed water is allowed to accumulate in the pipes, it is impossible to maintain a uniform temperature; besides, the water condenses the steam and is therefore uneconomical, and, from the possibility of the production of a vacuum, also dangerous.

FIG. 67.

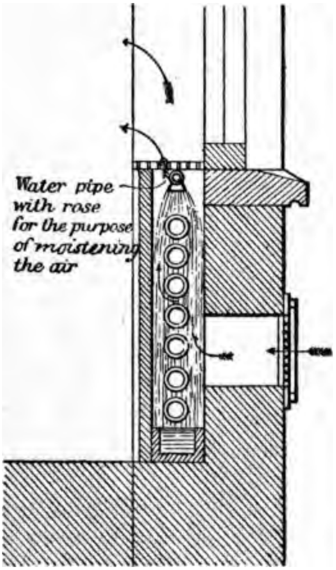
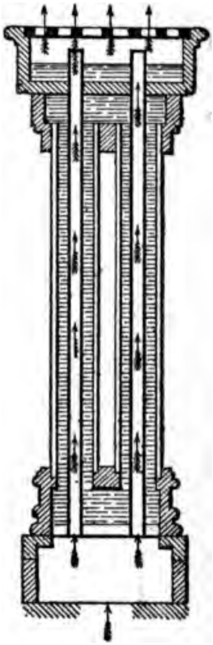


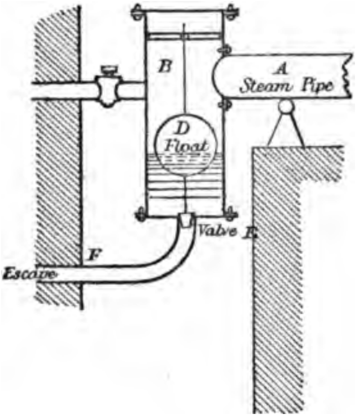
FIG. 68.



The following is a description of Tredgold's arrangement for removing condensed water (see Fig. 69). B is a square box attached to the end A of the steam pipe; D is a hollow copper cylinder fixed to a conical valve E; when steam is condensed the square box gradually becomes filled with water, which, at a certain height, lifts the conical valve E, and the water is allowed to escape and pass into the outlet pipe F.

Small wrought-iron pipes of three or four inches in diameter are much preferable to those of cast iron, as the heat conductivity of the relatively thinner wrought iron is much greater than that of cast iron.

FIG. 69.



Figs. 70 and 71 represent Messrs. J. L. Bacon & Co.'s arrangement of heating and ventilating workshops and factories.

When the steam or hot water cannot be obtained from the steam pressure generators, the tubular furnaces of Messrs. Weeks of Chelsea and Messrs. Bacon of London are the best.

The following is a fairly reliable formula for ascertaining the length of hot-water and steam pipes required to heat a building of any capacity, and to any desired temperature.

Let $P$ = Temperature of pipes.
$T$ = „ required in building.
$t$ = „ of external air.
$C$ = Cubic feet of air required to be heated per minute.
$L$ = Length of pipes in feet.

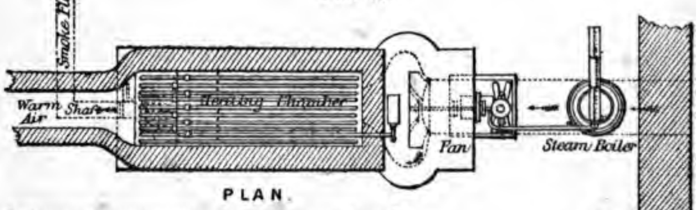
$$\text{Then } L = \frac{(P - t)(T - t)}{P - T} \begin{array}{l} \times\ 0{\cdot}0045\ C \text{ for 4-inch pipes.} \\ \times\ 0{\cdot}000\ C \text{ for 3-inch pipes.} \end{array}$$

The following is also a capital and reliable formula to ascertain the length of steam pipes required to heat the air to any required temperature.

Let A = Cubic feet of air required to be heated per minute.
B = Temperature of external air.
C = „ required in building.
D = Constant 2·1.
E = Constant 200.

Then $\dfrac{A \times B}{D E - \left(\dfrac{B + C}{2}\right)}$ = the superficial surface of steam pipe required.

FIG. 70.



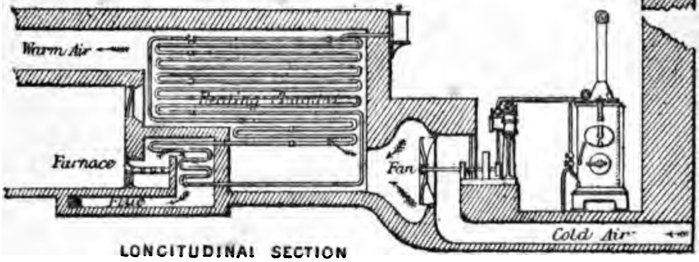


FIG. 71.

Example—Let A = 200.
B = 30° Fahr.
C = 70° Fahr.

Then $\dfrac{200 \times 30}{2{\cdot}1 \times 200 - \dfrac{(30 + 70)}{2}}$ = 16 superficial feet of steam pipes required.

Sixteen superficial feet multiplied by two will give the lineal length of 2-inch pipes, and by four will give the lineal length of 1-inch pipes.

## CHAPTER XIV.

### NATURAL LIGHT.

THE influence of natural or solar light on the condition of life cannot be over-estimated; in its absence both plants and animals etiolate. The effects of the absence of natural light are soon evident: the physique and health deteriorate and the eyesight becomes impaired.

No artificial light can take the place of sunlight nor exert the same influence.

The beneficial rays of the sun promote ventilation, and act, not only as disinfectants producing ozone, but dry up fœtid matter.

The vigour of the workpeople is stimulated and refreshed in the presence of the glorious sunbeams; how important, therefore, that ample light openings should be provided, to allow the sunbeams to enter and illuminate the darkness, promote life and destroy disease.

The best aspect for light openings is the south-easterly, so that the sun's rays may enter on both sides.

In arranging the light openings of factories and workshops, it is important that all the available area of the external walls exposed to light should be utilised, of course, with proper regard to structural safety.

The points of support which take the thrust of the arches and carry the girders, should be constructed in the form of buttresses, and as compact as possible, and the area between the supports utilised for light openings, which should extend from floor to the under side of ceiling. The glass of the windows at the floor level may be protected by a light form of railing. Figs. 72 and 73 show the great advantage of this arrangement in comparison

FIG. 72.

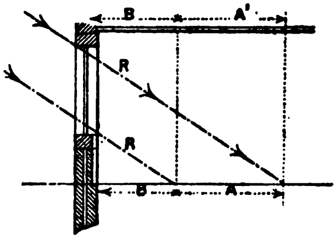


FIG. 73.

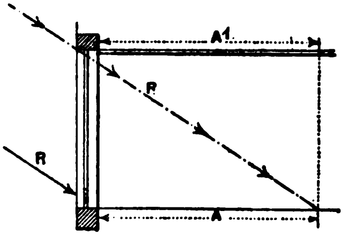
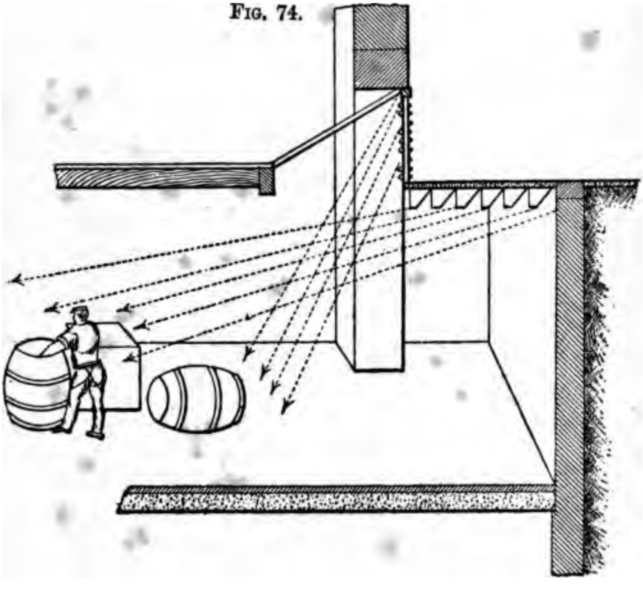


FIG. 74.

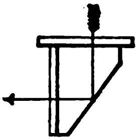


with that of the ordinary one. The rays of light are assumed to fall at an angle of 30° to the horizon. R represents the rays of light; A the surface illuminated;

$A^1$ the surface illuminated by reflected light; B the surface in shade.

Factories as ordinarily constructed are very defectively lighted, and it will be obvious that the great width of the rooms, even with the greatest provision possible for the entrance of light, will prevent any great natural illumination, and when the light openings are small and scarce the result is shade, not light.

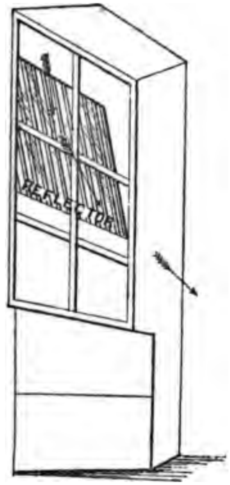
Fig. 75.



*Detail Hayward's Patent Semi Prismatic Lens.*

The first cost of a structure, with the suggested arrangement of light openings, would be slightly increased, but the hours of labour by natural light would be extended during the winter months from 30 to 60 minutes according to the height of the rooms. The increased natural illumination would assist labour, benefit health, and the extra cost of the structure would be amply recompensed.

Fig. 76.



For the lighting of basement floors, coal gas is most commonly used. Nothing can be more injurious to the health than underground workshops, filled as they commonly are with gaseous exhalations rank and fell. Moreover, the eyesight is rapidly impaired by the constant use of impure gas light.

Wherever possible, natural light should be obtained by means of reflectors.

Figs. 74 and 75 represent a method of obtaining light in this way.

The light is reflected through Hayward's patent semi-prismatic lens in the direction shown by the arrows. The reflecting face is at such an angle as to send the rays of light into the basement in a direct line from the front.

Fig. 76 represents Chappuis' louvre reflector system of basement illumination.

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## CHAPTER XV.

### ARTIFICIAL LIGHT.

At the present time the universal system of artificial lighting is by means of coal gas; as ordinarily used this system is anything but satisfactory from a hygienic point of view, as not only does the gas consume, as we have already shown, an enormous volume of oxygen, but the products of combustion, often very hurtful, are allowed to contaminate the air necessary for breathing. Inferior coal gas commonly contains as much as 20 per cent. of carbonic oxide. The inhalation of this gas renders the blood corpuscles useless. Another highly poisonous resultant of coal gas illumination is acetylene. Sulphuretted hydrogen and sulphuric acid are largely generated when burning low quality coal gas; both these gases are exceedingly deleterious. Many of the modern diseases are, according to the medical profession, distinctly traceable to the injurious effects of the inhalation of these products.

A very general manner of heating a room is to light the gas, and allow the heated products of combustion to diffuse in the air; a more insanitary method can hardly be realised.

The vapours given off by burning coal gas should not be allowed to pollute the breathing air, but should be led away by a separate and special channel.

The simplest arrangement for the removal of the products of combustion is to fix a bell-mouth of glass or zinc over the light, with a tube for carrying away the resultant noxious vapours. The greatest care must be taken in fixing the outlet tube to guard against the danger of outbreak of fire.

A system devised by the author consists in enclosing the gas removal tube in another tube for supplying the air to the burner, the heated gases escaping would thus heat the incoming air supply, and a more brilliant light would be the result. The heat of the products of combustion is also utilised to extract the air. (See Fig. 77.)

FIG. 77.

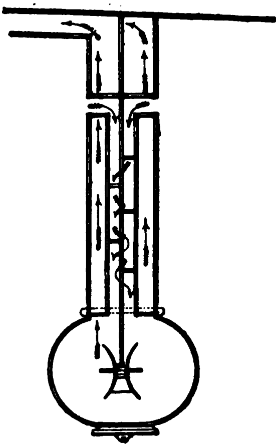
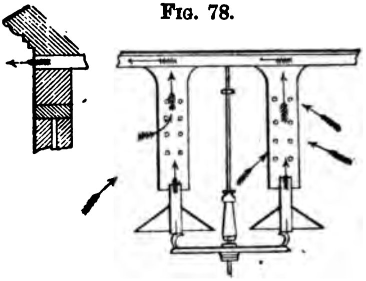


FIG. 78.



For offices a good arrangement is shown in Fig. 78, which also acts as an exhaust ventilator.

Reckett's ventilating globe light is a very admirable contrivance. (See Fig. 79.)

Messrs. Benham and Strode and Sons, London, have made some very good improvements upon Reckett's arrangement.

Fig. 80 shows the sun-burner ventilating light.

For large buildings where gas burners are used, the heat generated by the gaseous combustion can be utilised for extracting the vitiated air (see Fig. 81); in fact, wherever gas is used, no difficulty should be experienced in the proper supply of pure air.

FIG. 79.

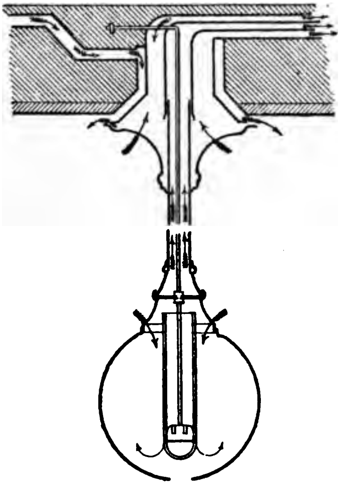
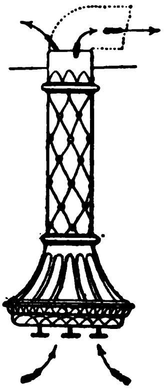


FIG. 80.



By a simple arrangement the pure air supply can be agreeably heated to the desired temperature, and by arranging one or a number of burners according to the size of our outlet upcasts, the vitiated air can also be drawn away.

Every gas jet should be provided with an inverted funnel terminating in a main outlet duct, or passing direct into the open air. (See Fig. 82.)

The more concentrated the arrangements of lights are, the better. In large workrooms, lights of the most perfect form should be arranged along the walls and in the main footways, and fitted up with powerful reflectors. This system would simplify the arrangement and number of the gas outlet ducts. Powerful lights uniformly distributed are far more efficient, safe, and economical, than a larger number of small, inferior, and poisonous burners badly distributed. Besides, the badly arranged burners so often tampered with by workmen are amongst the most prolific of the sources producing fire.

Fig. 81.

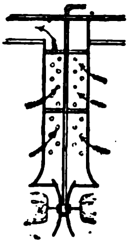
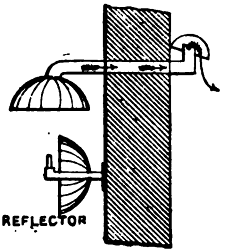


Fig. 82.



For office purposes green shades are often used, and are commonly formed of deleterious materials. Shades can, however, be obtained of pure material from Messrs. Sharlands, of 69 Fleet Street, London.

### *The Electric Light.*

The author expressed the following opinion as to the sanitary qualities of the electric light some years back in the columns of the *Engineer*, viz., " That owing to the intense heat of the voltaic arc, the mechanical union of nitrogen and oxygen which constitutes atmospheric air would probably be destroyed, and that the reaction would be similar to the changes effected by lightning, e. g. that the nitrogen and oxygen would chemically combine, forming oxides of nitrogen, which are mostly poisonous compounds."

Some time after the subject was practically investigated by Mr. Willis, F.C.S., who described the result of his investigations as follows:—"The atmosphere, of course, consists mainly of oxygen and nitrogen, but simply in a state of mechanical mixture; if these gases chemically combine they form several oxides of nitrogen, most of which are strong and corrosive acids; at a high temperature small quantities of these gases can be made to unite. This is the case when electric sparks are passed through the air, and the same thing takes place during the combustion in air of a very hot flame, such as that of hydrogen. It therefore seems probable that as the temperature of the electric arc is undoubtedly very high, nitric acid or some other oxides of nitrogen might be produced by the electric light."

The first experiment was rather surprising; a glass cylinder placed over an electric lamp (Foucault's regulator) for two minutes and afterwards examined, was seen to contain a perceptible amount of red fumes due to peroxide of nitrogen.

The air surrounding the lamp was next drawn through a solution of potash and the amount of nitric acid estimated; this gave a production of from 10 to 12 grains of nitric acid per hour; this quantity may, however, eventually prove to be more; the difficulty is found in collecting the whole of the acid of this process. Of course, the amount of oxides of nitrogen will vary with the description of lamp; whilst if the light is produced in vacuo, the surrounding air will, of course, not be in the least degree contaminated, so that we may conclude that the most perfect form of artificial light from a sanitary point of view is the electric light produced in vacuo.

From the results of experiments lately carried out by Dr. Siemens, F.R.S., for ascertaining the influence of the electric light upon vegetable life, it appears that although carbonic acid and other nitrogenous compounds are generated by the electric arc of the Siemens lamp, their diminutive quantities produce no sensibly deleterious effect on plants.

Dr. Siemens found that the electric light was a valuable auxiliary to natural light, and that plants make increased and vigorous progress if subjected during the daytime to sunlight, and during the night to the electric light.

There is every reason to believe that the electric light, which is so valuable a stimulant to vegetable energy, has an equally stimulating effect on the animal energy. From a hygienic point of view, at least, the electric light has been proved to be decidedly superior to gas light, and sanitary reformers are awaiting with great interest the results of further researches in this direction.

It is satisfactory to note that the electric light has now fairly passed the experimental stage, and is gradually coming into use for lighting factories and workshops.

# PART IV.

## ARRANGEMENTS FOR THE PREVENTION OF ACCIDENTS.

## CHAPTER XVI.

### EMPLOYERS' LIABILITY ACT.

ALTHOUGH humane and intelligent manufacturers have always shown a disposition to adopt all necessary means for the prevention of accidents, the arrangements in general use are very inefficient, and dreadful accidents occur hourly, which by a simple exercise of caution might never have happened. Surely manufacturers will not deny that they are responsible for the accidents which occur from exposed machinery, which might have been protected at a small cost: although dangerous machinery may be exposed for a long time without causing any accident, because the workpeople have been cautious and fortunate, yet in some fatal moment they become confident, and do not exercise the prudence necessary for their safety, until at last a horrible accident reminds them of their indiscretion. It is to be hoped that the "Employers' Liability Act" of 1880 will have the effect of enforcing such arrangements of protection to the workpeople as will reduce the chances of accidents occurring to a minimum.

The following is a brief outline of the principal clauses of the Act:—

"On and after the first day of January 1881 employers are held liable to make compensation for personal injuries suffered by workmen in their service from any of the causes specified by the Act.

"Where after the commencement of this Act personal injury is caused to a workman

"(1) By reason of any defect in the condition of the ways, works, machinery, or plant connected with or used in the business of the employer;

"(2) By reason of the negligence of any person in the service of the employer, who has any superintendence entrusted to him whilst in the exercise of such superintendence;

"(3) By reason of the negligence of any person in the service of the employer, to whose orders or directions the workman at the time of the injury was bound to conform, and did conform, where such injury resulted from his having so conformed;

"(4) By reason of the act or omission of any person in the service of the employer done or made in obedience to particular instructions given by any person delegated with the authority of the employer in that behalf;

"The workman, or, in case the injury results in death, the legal personal representative of the workman and any person entitled in case of death, shall have the same right of compensation and remedies against the employer as if the workman had not been a workman of nor in the service of the employer nor engaged in his work."

## CHAPTER XVII.

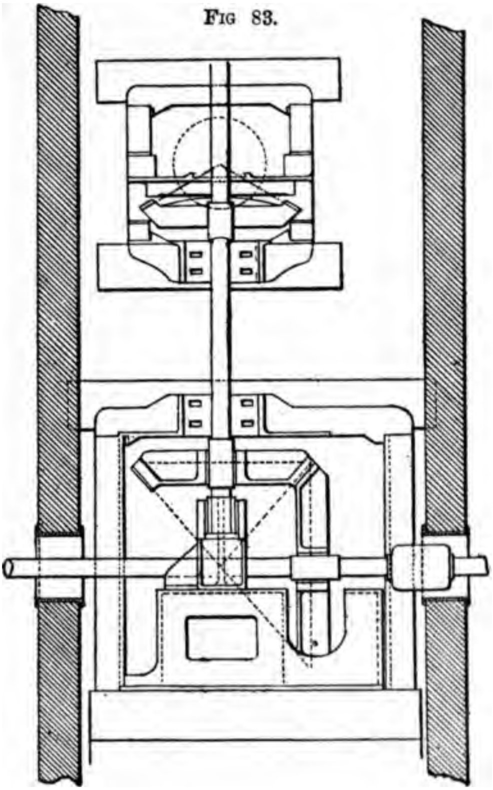
### SHAFTING, BELTING, GEARING, HOISTS, ETC.

THE shafting and machinery for the transmission of power should be rendered as harmless as possible by moveable covers of tinplate.

Shafting which passes between detached buildings should be placed either a considerable distance above the surface of the ground intervening between the buildings, or placed in a covered trench below the surface.

If any gearing or belting is on the external side of a building, it should be covered with cast-iron plates, brick, or masonry, with moveable openings for lubrication.

FIG 83.



In the transmission of power in a vertical direction, the upright shafts should be erected in a separate walled tower (Fig. 83). The footsteps should be supported on a massive foundation.

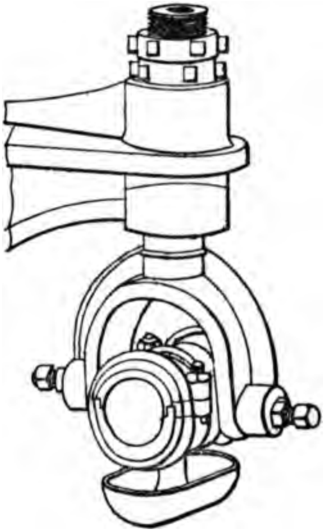
The tower should have openings for lubrication and examination; the openings closed by means of iron doors. By this arrangement a firmer bearing than wall brackets can be obtained for the shaft, and increased facilities for working at the adjustments are provided; the bearings are protected from dust and other substances which cause friction; another and most important advantage is that in case of the fracture of the shafting, gearing, &c., the damage is confined to the interior of the tower; further, the oily medium of lubrication is prevented from contaminating the clothes, the perfect protection of the workpeople is secured, and in case of the overheating of the bearings there is no danger of fire originating.

One of the causes of fractured shafting, and overheating of the bearings, is the enormous friction exerted by a shaft supported on a fixed bearing, transmitting power by a belt; the pressure on the bearing is thus greatest in the direction of the line of belting. To remedy this, several inventions have lately been successfully applied, and some are already in extensive use in the United States. One of the inventions known as the self-adjusting, self-lubricating hanger is excellent (see Fig. 84). The construction of the bearing is of the nature of a universal joint; therefore, in whatever direction the shaft inclines, an equal strain is brought upon the whole bearing surface of the journal, thus eliminating all tendency to the unequal application of pressure, and consequently decreased liability to overheating; by an ingenious arrangement the oiling is effected by capillary attraction, and the bearing is thus supplied regularly with lubrication.

When the power from the engine is transmitted by belting driven direct from the flywheel, the passage of the belting should be distinctly isolated. The method of driving from the flywheel is attended with great danger, especially in the action of fixing the belting on the fly-wheel.

When ropes are used instead of belting, the greatest care should be taken to ensure a proper splicing of them; the splicings should be equally as strong and of the same size as the rest of the rope; if they are made larger they produce an ununiform transmission, or if weaker they break prematurely, often producing accidents.

FIG. 84.



Rope driving arrangements are successful if a sufficient number for possible requirements are provided in the first instance.

They must, however, be carefully watched, and the least defect promptly remedied.

When the distance of transmission from the prime mover to the secondary motion or drum is very great, the fall of such a length of roping in case of breakage would prove very serious. To modify this possible evil, wrought-iron bars should be provided and fixed at certain distances, in such a way as to catch the roping in case of fracture.

Terrible results occur daily from defective arrangements and bad management of belting.

The management of belts may be divided into five operations, as follows:

1st. To put a belt in its place.

2ndly. To sew, splice or to attach the two extremities of the belt.

3rdly. To fix a belt upon the driving pulley, &c.

4thly. To pass the belt from the loose to the fixed pulley, and *vice versâ.*

5thly. To lower the belt from the driving pulley in order to stop the transmission of power for the purpose of examination and repair; the driving belt in all these operations (with the exception of that of moving the belt from the loose to the fixed pulley, and *vice versâ*) is allowed to fall on the shaft if there is no arrangement to prevent it.

The belt rests upon the shaft for a longer or shorter duration, according to circumstances. The position of the belt resting upon the revolving driving shaft for the purposes of repair, &c., is that pregnant with the most dangers. If the belt rests on the driving shaft, the workmen have to prevent it from being entwined round the revolving shaft, by removing the belt from contact with the shaft; very often when the belt has been allowed to rest on the shaft it has gradually become entwined with its motion, often entangling with it the workmen, and everything that opposes its progress. This occurs very frequently, and is the prolific source of accidents. The danger which it presents is increased according to the flexibility and adhesion of the belt, and in proportion to the increase of width; the most dangerous are those of one to three inches in width.

The direction of the belt upon the shaft has a great influence upon its safety, as well as the way in which it rests upon the shaft. The condition of the latter facilitates the motion of entwining, which is also effected by a great velocity or an irregularly turned surface of the shaft, although however smooth or turned the shaft may be, the belt has a tendency to be (and often is) dragged round with it. The entwinement occurs when one side of the belt not in tension hangs loosely in a curve and comes in contact with the other or tension side of the belt; in this way the loose belt is often carried round the shaft with the belt in tension, followed by the inevitable disaster. To further explain. Let us examine a belt resting upon a moving driving shaft whilst repairs are being made. The workmen who maintain hold of the belt have often the unfortunate habit of holding both sides tightly together. (See Fig. 1, Plate I.) If they give way a little to the movement of the shaft, the arriving belt will come in contact with the receding one. (See Fig. 2, Plate I.) The belt gradually assumes the form Fig. 3, and eventually both sides become entwined round the shaft.

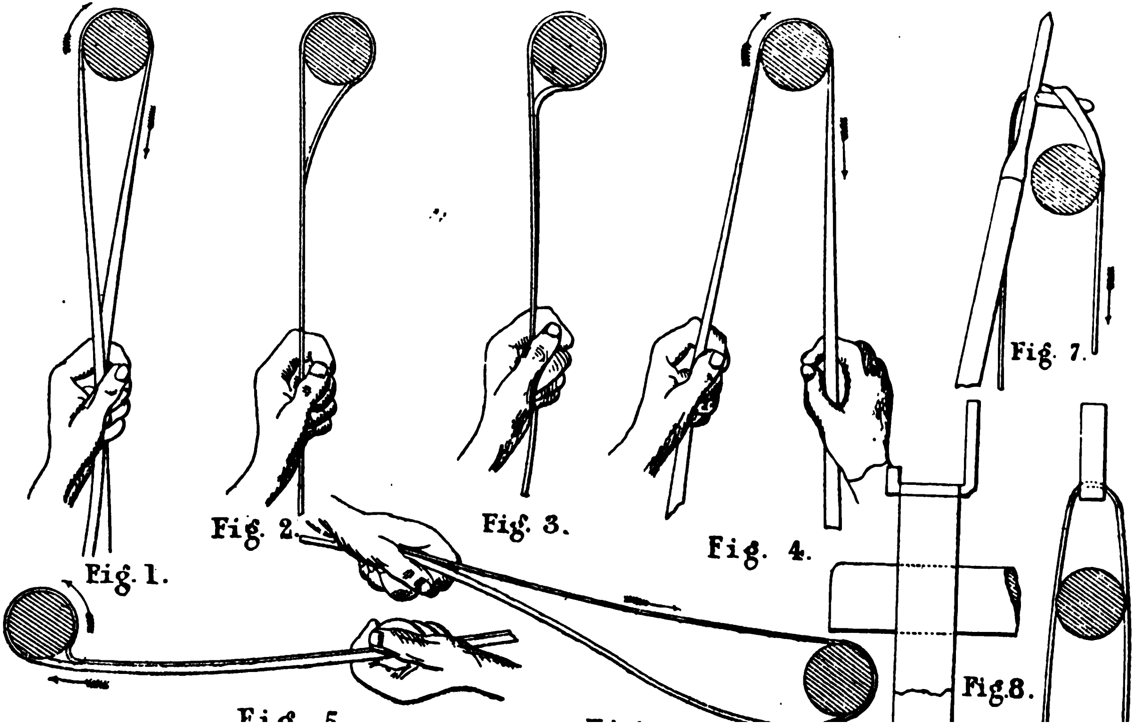
It has already been noticed that the flexibility and adhesion of the loose side belt increase its tendency to repose on the tension or tight side. If the workmen held each side of the belt separately (see Fig. 4) this danger would be avoided. The belt would be supported and friction diminished, and the fatal action of entwining would not occur. The entwinement will occur in a similar way to belts which transmit power in a horizontal direction. When the tension side of the belt is the lowest the higher or loose side will hang loosely, and come in contact with the lower or tension side (see Fig. 5); but if the tension side of the belt is highest, there is no danger of contact whatever (see Fig. 6).

The possibility of the danger of entwining depends, therefore, on the relative position of the tension side of the belt to the loose side.

In Plate II. are shown the various positions in which pulleys and belts are commonly placed, showing both parallel and crossed belting.

The pulley A is in all the figures the drawing or motive pulley.

PLATE I.



Vertical direction, Figs. 2, 3, 4, and 5.

Fig. 2. This arrangement of belting does not present any elements of danger; it hangs loosely since it is not in contact with the driving shaft.

Fig. 3 is also a safe arrangement, although the belting is crossed; if the sides of the belt do come in contact, the fact of the driving pulley being the lowest, prevents the probability of danger.

Figs. 4 and 5 are dangerous examples, because the belting rests upon the revolving driving shaft. The crossed belting arrangement is more dangerous still, as the friction of contact is increased.

Figs. 6, 7, 8, and 9. Horizontal direction.

The positions 6 and 8 are not dangerous, the hanging of the lower and loose belt preventing contact.

Figs. 7 and 9 present examples of the greatest danger, the catenary curve formed by the loose side of the belt bringing it in contact with the tension side, with which it is often entwined.

Figs. 10 to 17. Oblique directions.

Dangers of these positions are similar to those of the horizontal arrangements.

Figs. 10, 11, 16, and 17 do not offer any danger.

Figs. 12, 13, 14, 15 are dangerous examples.

As a general rule, the most dangerous arrangements of belting in horizontal and oblique directions are those where the tension side of the belt is lowest.

### *The Proper Handling of Belts.*

To put a belt in position, workmen have various methods, following circumstances or habit. Sometimes they take one extremity in one hand, whilst with the other hand they throw the remainder of the belt over the moving shaft in the *direction of its movement*, allowing the other extremity to rest on the floor.

PLATE II.

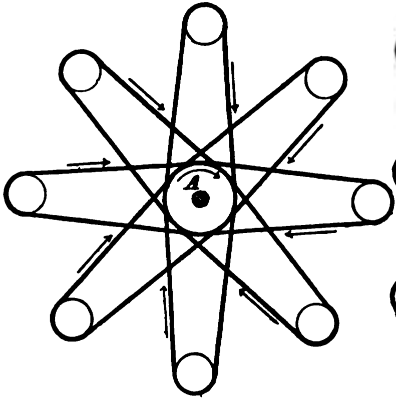


Fig. 1.

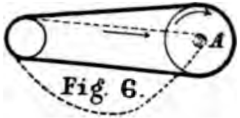


Fig. 6.

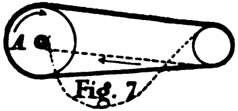


Fig. 7.

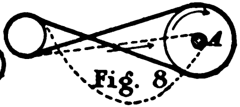


Fig. 8.

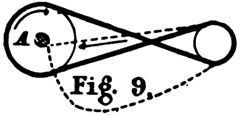


Fig. 9.

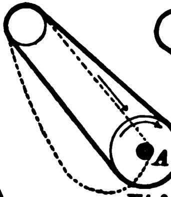


Fig. 10.

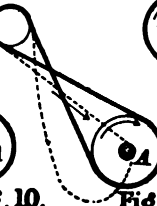


Fig. 11.

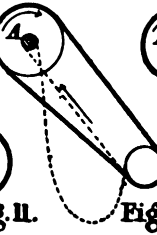


Fig. 12.

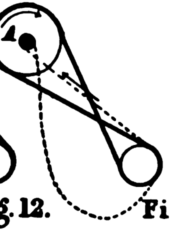


Fig. 13.

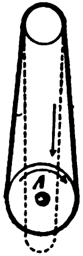


Fig. 2.

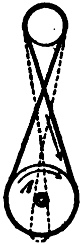


Fig. 3.

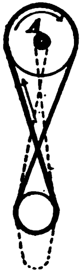


Fig. 4.

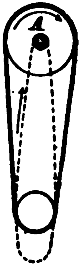


Fig. 5.

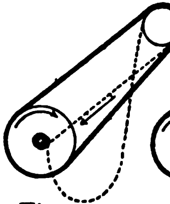


Fig. 14.

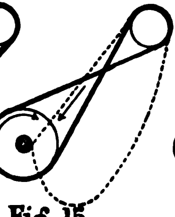


Fig. 15.

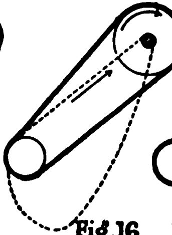


Fig. 16

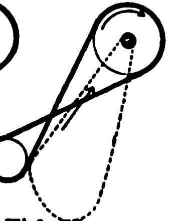


Fig. 17.

This plan is dangerous, for often the belting becomes rapidly entwined round the shaft.

The workman should place himself in such a position that the direction of the movement of the shaft is towards him; there would be less tendency in this case for the belting (thrown as it would be in opposite direction of the movement of the shaft) to become entwined; and by holding both sides of the belt as shown in Fig. 4, Plate I., there would be no danger at all.

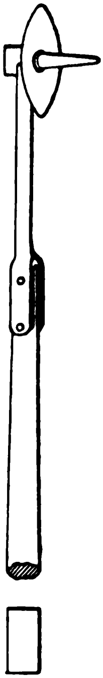
Sometimes before the belting is thrown over the shaft, it is rolled up at the extremities so as to produce weight, to prevent the belt from returning over the shaft. This is a good plan.

Although belt shifters are very useful and safe contrivances, they are rarely at hand when required, and the workmen will not trouble to search for them; or even when the appliance is at hand they neglect to use it, and an accident eventually happens.

If there are no other arrangements for unshipping the belting, the employment of the portable belt shipper (see Fig. 7, Plate I.) should be enforced.

An improved form of belt shipper has lately been devised (see Fig. 85), and is said to answer its purpose efficiently.

FIG. 85.



Although simple methods for the prevention of accidents have been invented, yet they are very rarely applied, owing to ignorance of their existence, or indifference to the safety of workmen.

The simplest arrangement for preventing accidents when the belt is required to be unshipped, is by means of a light suspended belt perch (see Fig. 8, Plate I.). This

PLATE III

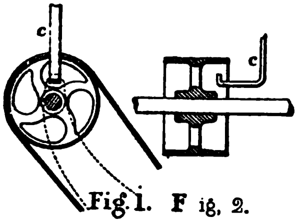


Fig. 1. Fig. 2.

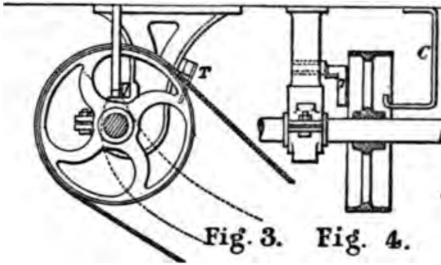


Fig. 3. Fig. 4.

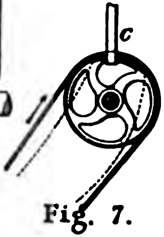


Fig. 7.

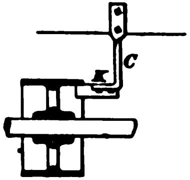


Fig. 8.

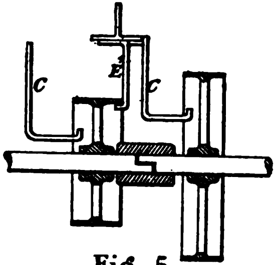


Fig. 5.

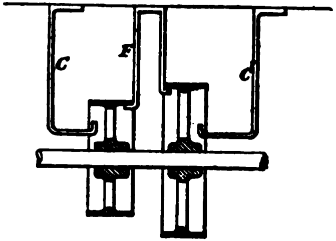


Fig. 6.

perch must be so disposed that the belt will fall safely upon it when removed from the pulley, until required either to be remounted on the pulley or taken down for repairs. During this process the workman will not require another assistant to support the belt, which rests on the perch, and he can have both his hands free without being exposed as formerly to a danger which varies according to the size and the flexibility of the belt, the diameter of the driving shaft, and especially its velocity.

Exceptional systems of transmission require particular arrangements to prevent the belt from falling upon the driving shaft, as for instance when the pulley is near a coupling cylinder, wall or other object, or if two pulleys are placed side by side (Fig. 6, Plate III.) upon the same shaft and separated by a space in which the belt could fall. It must be prevented by some arrangement from so doing, otherwise it would be difficult and dangerous to replace the belt during the movement of the shafting and pulleys.

For a drum placed near a wall or a support, it suffices to fix to the latter a perch C, Fig. 4, Plate III., and a cranked bar T, Fig. 3, to prevent the belt from falling between them when the pulleys are running side by side; a double perch should be fixed under the rim and bent upwards, so as almost to touch the rim of the pulley; if a crank guide is used to prevent the belt from falling from the pulley, to be effectual it must be placed as near the rim as possible (without actually coming in contact), otherwise there will be a danger of the belt twisting, and falling between the rim of the pulley and the guide.

If the driving pulley is the lowest, and in a vertical direction or a little oblique below the secondary pulley, a perch is almost useless, as the belt cannot be caught or entwined, because the loop formed by the suspended belt, if it rests upon the secondary shaft, will hang clear of the lower or revolving driving shaft. If, however, the angle of the direction of transmission is an acute one, it is prudent to place a safety guide. Of course the strength of the bar which forms the perch must be proportionate to the length of its suspended and horizontal members, and the width, length, and thickness of the belting. It can be made of round bar iron of a diameter of $\frac{5}{8}$ inch to $\frac{7}{8}$ inch, or of flat iron of a thickness of $\frac{3}{8}$ inch to $\frac{1}{2}$ inch, and a width of from 1 inch to $1\frac{1}{2}$ inch.

### *Explanatory Table of Simple Safety Guides or Belt Perches, Represented in Plate III.*

Figs. 1 and 2 represent a pulley accompanied by the ordinary perches destined to receive the belt when it is unshipped. This arrangement is the most general one in use.

Figs. 3 and 4 show a pulley placed near a hanger, furnished with a crank guide, to prevent the belt from falling between the hanger and the pulley. The guide is arranged so as to act before it comes into contact with the pulley.

C is the perch, T is the guide.

Fig. 5 shows an arrangement of two drums separated by a coupling clutch, on which the belt should not be allowed to fall. It will be seen that each pulley is furnished with a carrier and a guide $E^1$, placed so as not to allow the belt to fall upon the clutch.

Fig. 6 represents two pulleys placed side by side, separated by a space in which the belt should not be allowed to fall.

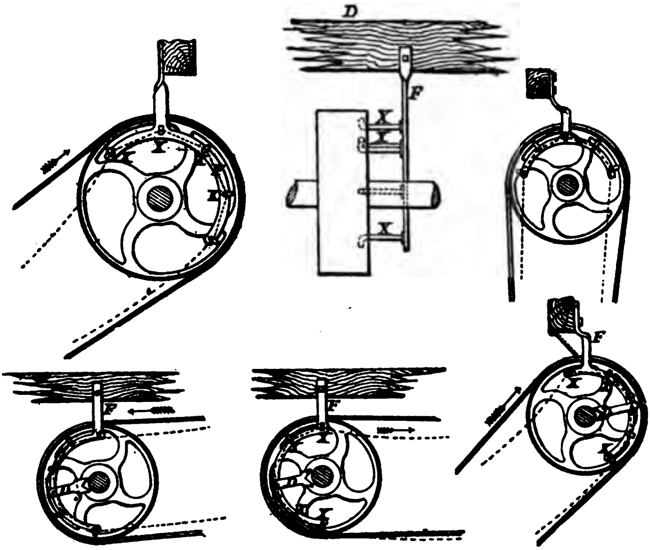
In Fig. 6, C and $C^1$ are the belt perches for each pulley, and F a bar doubly bent forming a double guide.

Figs. 7 and 8 represent an arrangement of belt perches applied at the spinning mill of MM. Ch. Mieg & Co., of Mulhouse.

C, belt perches; K, wrought-iron carrier attached to the latter to facilitate the mounting.

The arrangement invented by M. Biedermann, of Logelbach, is a great improvement on the ordinary method, and is successfully in use on the Continent (see Fig. 86).

Fig. 86.



It consists of a segment of flat iron F arranged concentrically to the pulley. This flat segment carries five or six pins * X, which project under the rim of the pulleys. The first pin is placed where the belt arrives, and comes in contact with the rim of the pulley and the last one at the point of departure. The bars X constitute the carrier for the belt, and they can serve the purpose of a loose pulley. For the practical working of this system, use is

---

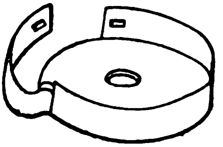
* When the transmission of power is in a horizontal direction, to prevent the perch from becoming disturbed, use is made of a resisting piece of timber D, which falling on the shaft if the belt perch is subjected to severe strain, prevents any serious effect.

made of the portable belt shipper to push the belt a little against the pulley, and without the least effort to ship it by pressing the belt, and *vice versâ* to unship it. Very little effort is required. The whole cost of the article will not exceed ten or twelve shillings each.

### *Spur-gearing.*

Many accidents occur from the imperfect fencing of spur-gearing. The arrangements generally adopted do not sufficiently cover up the gearing: this is especially the case in moveable covers. The arrangement shown in Fig. 87 represents an improvement on the general form of wheel casing, by which the wheels can be entirely encased, and oiled without entirely removing the casing.

Fig. 87.

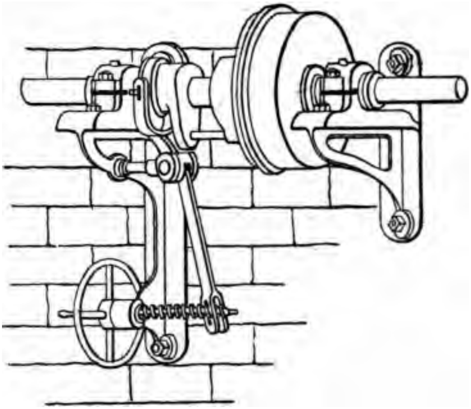


All gearing should be as far as possible cased off. By a simple device, lubrication could be effected without the removal of the casing. Wheel casings are certainly productive of economy, as, independent of their sanitary importance, they prevent dust, &c., from clogging the lubrication and impeding the movement of the gearing, and in case the shafting become overheated from defective lubrication, they prevent the danger of fire.

### *Machines.*

All intricate and dangerous machinery should be effectually fenced, and where possible every machine should have a separate arrangement for instantly stopping its motion; either by Seller's arrangement, or the excellent invention known as Addyman's American Friction Clutch (see Figs. 88, 89, and 90), or by a loose and fast pulley, with a simple and substantial strap shifting arrangement. The too prevalent practice of removing the belt on to the shafting to stop the machine is exceedingly dangerous, and should be prohibited.

FIG. 88.



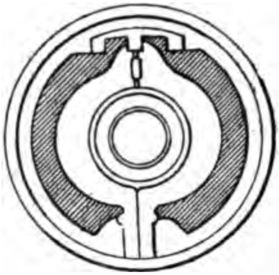
Footways between machines should be at least three feet in width, and constantly kept clear so as to allow unimpeded movement for the workpeople.

### *Hoists.*

The extension of the use of these admirable contrivances has unfortunately been productive of many fatal accidents, either from defective roping, gearing, and brakes, or by falling down the hoist wells. A simple and safe hoisting motion is obtained by a worm-wheel and worm driven by crossed or open belting; on the worm-wheel shaft are three grooved pulleys, over which are passed separate ropes fastened to the hoist and balanced by weights, so that it is always safe and quite independent of propelling motion. The centre rope is left slacker than the two outer ones. The whole machinery is in sight from base to summit.

The lifts made by the following makers are safe, effective, and noiseless in their action:—J. Stannah, of London; J. Thomas and Sons, of Cardiff; and Messrs. Clarke and Messrs. Bunnett, and Co., of London.

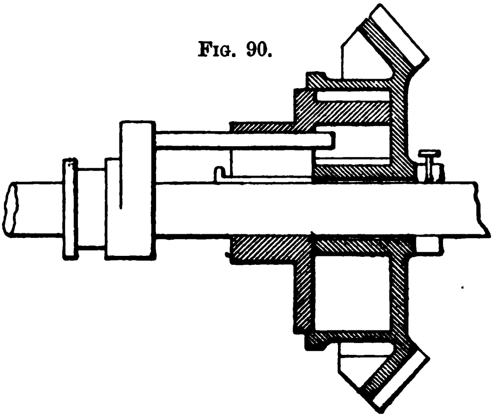
Fig. 89.



Chains or wire ropes should be used in preference to hempen ropes.

In the United States a system of hoisting is coming into use by means of a vertical screw, which runs up the centre of the hoist well; this screw is caused to revolve, in either direction, by means of steam power; the screw passes through the centre of the cage, to the bottom of which rollers are fixed, working in the thread of the screw and forming the nut. This system, although rather slow in action, is exceedingly safe, and deserves extensive application.

Fig. 90.



The patent hoist governor, patented by Brown and Westhead, made by Bailey and Co., of Salford, is an excellent contrivance. The following is a description.

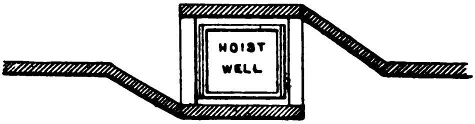
On the top of the hoist is placed a pair of governor balls, receiving motion through a pulley and bevel wheels from a friction pulley, which is held against the guide by a spring; on each side are two shafts, on the ends of which are four serrated cams. When the hoist is in motion, it will work freely without hindrance from the brake cams; but the instant that the hoist exceeds the limit at which it is intended to work, the governor balls fly apart, release the latch, and set free the cams, which are thrown out against the guide by means of the weighted levers, and instantly stop the further descent of the hoist.

Bunnett's safety contrivances are also commendable, especially their safety hydraulic direct-acting hoist. This hoist is entirely under the control of persons inside the cage and at any floor.

By simply pressing a small knob fixed inside the cage, the lift can be arrested at any desired level. On each floor is fixed an index plate, denoting the precise position of the cage, and by moving a handle in connection therewith, any person can bring the cage to the floor where it is required. Immediately the cage begins to ascend or descend, the outer doors are self-locked, and cannot be opened until the cage arrives at each floor; by this means no one can fall from the cage down the well hole. Should any derangement of the valve take place, the ram cannot possibly leave the gland, as immediately it rises above the proper level, the water, instead of exerting any pressure on the ram, passes into the waste pipe. As to the hoist, the stronger it is built the better. The roof especially should be of the firmest description, for protection from any falling bodies.

Door openings are often placed in hoist wells opposite each other, and on the same level, so as to serve two rooms. This practice is attended with danger, especially to strangers, and has been productive of numerous fatalities. In well-lighted rooms where hoist wells are thus arranged, an optical illusion is produced, which gives to a person unaware of the existence of a hoist well the impression that no well hoist really exists. When a hoist has to serve the purposes of two rooms on the same level, the safest plan is to have the hoist wells and door openings arranged, as shown in Fig. 91, so as to prevent the passage of the flood of light which produces the curious illusion mentioned.

Fig. 91.



Openings to hoist wells should be provided with self-closing doors.

Doors opening into hoist wells should never be opened except for the purpose of entering the hoist.

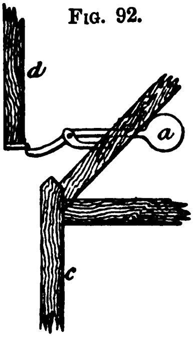
A self-acting arrangement for closing and opening room doors in hoist wells is shown in Fig. 92, applicable to one or more storey hoists.

The arrangement consists of a weighted lever *a* supported on the bearing *b* fixed at the top of the cage. One end of the lever is flattened. The joint of the lever must be of the ordinary hinged kind, so as to prevent the weight from falling below the horizontal position.

The hoist doors *d* should be hung by weights and cords similar to house window sashes, and sliding in grooves; the under side of the door must have a projection to correspond in size to the flattened end of the lever. The weight must be slightly heavier than the door.

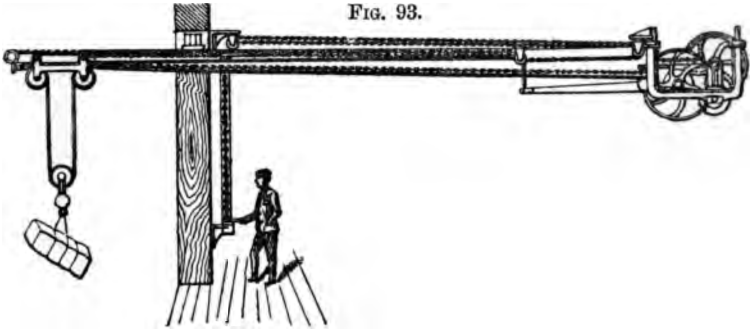
The action is as follows. The flat end of the lever, when the hoist is ascending, will meet the projection and lift the door, and when the hoist is descending, the door, which is hung by cords and weights, will fall, and thus close the door opening. In buildings where there are several storeys, by the simple attachment of a cord to the lever, the occupants can by pulling the lever down prevent any door from being lifted except the one desired. In buildings where there are extensive hoisting appliances, they should be placed under the control of a reliable workman, who should be held responsible for the proper working and maintenance of them.

Fig. 92.



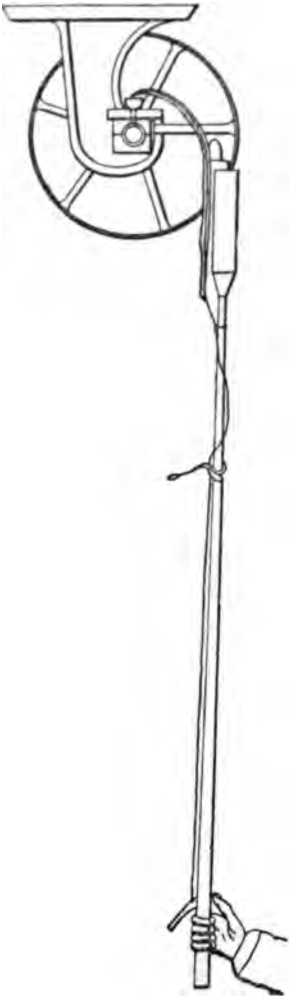
The cat-head method of hoisting is exceedingly dangerous, and is the cause of numerous accidents. A great improvement on this form of hoist has lately been introduced (and is being extensively adopted), made by Mr. J. Barker, of Oldham, and is excellent in every respect (see Fig. 93).

Fig. 93.



This hoist will not only lift goods from carts, &c., but will carry them into the rooms, thus dispensing with the laborious and hazardous task of pulling the goods on to the door threshold by means of hand hooks; they will also act *vice versâ* as required, obviating the risk of having the goods pulled off the doorstep, and the danger of their falling to the ground.

FIG. 94.



Where the ordinary cathead hoisting arrangement is in use, a projecting light landing should be arranged on one side of the door opening, so as to facilitate the work of moving the goods on to the threshold of the opening; or, better still, the landing could be made to extend the whole width of the door and have double-hung trap-doors, so that the materials when they are lifted up should open the doors, which, of course, would fall by their own weight, and form a floor to receive the goods, when they could easily be removed into the rooms.

All cutting machinery should as far as possible be made safe.

To ward off the shock of massive saws working horizontally, safety frames should be provided; on sawing with circular saws, a false piece of wood should be placed against the timber to be cut, so as to prevent risk to the hands.

Workmen employed in supervising machinery should be prohibited from wearing loose and flying garments; they should be compelled to wear close-fitting habiliments.

All lubricating arrangements should be as free as possible from danger; the lubrication of machinery in motion should be strictly prohibited.

In order to lubricate overhead gearing, workmen have a very bad practice of mounting a ladder which is placed against the revolving shaft. By the admirable arrangement shown in Fig. 94—Radcliffe's patent shafting oil-can—the lubrication of overhead gearing can be accomplished with safety.

## CHAPTER XVIII.

### THE MANAGEMENT OF THE STEAM GENERATOR FURNACE.

If the management of steam boilers and furnaces were consigned to stokers of intelligence and sober habits, and properly trained to their respective duties, we should hear less of the terrible accidents which now and then horrify the public, and proprietors of steam engines would be more than compensated for the additional salaries they might have to pay such thorough and reliable workmen by the saving of fuel which would be the certain result of a more intelligent management, not to mention the benefit to public health from the non-emission of smoke from thousands of manufacturing chimneys.

The fireman's first duty is to ascertain the quantity of water in the boiler.

*Firing.*—If the fire has been banked, the process is simple; but if not, it must of course be rekindled, a process as ordinarily carried out producing a great amount of smoke.

To properly kindle a fire, after laying and igniting the wood and shavings, which must be dry, the smallest lumps of coal must be gently laid on the fire, merely to cover the burning material; after the first layer of coals is properly lighted, another layer of small coals must be gently laid and allowed to become properly ignited, and then another layer of small coals must be applied, and so on until the whole mass is in a state of complete combustion. If a large mass of coal is placed immediately on the fire, the top layers of coal will be slowly decomposed by the rising heat from the lower and ignited embers; the inflammable gases evolved, not coming in contact with sufficient heat to produce combustion, pass away as smoke.

To produce perfect combustion, the air should be heated before being allowed to mix with the inflammable gases.

Cold air, or oxygen, instead of combining with the hydrocarbon gases to form flame, neutralises the heat of the latter, and thus instead of producing perfect combustion, they pass away together in a state of mechanical mixture or smoke. In firing, this fact should be remembered. The fire should be kept in a ruddy glow, and not choked by a mass of coals: new fuel should be sparingly placed on the fire and not piled on in heaps. A good plan, after the coals are incandescent and when new fuel is required, is to make a trench in the incandescent embers with the spade, and place all the new fuel in the trench, piling the embers on the top; this practice would ensure the most perfect combustion.

In first preparing the fire, a good method is to cover the back of the grate next the bridge with the incandescent embers; this will prevent the inflammable gases generated in the front and body of the grate from passing over the bridge unconsumed. One of the commonest sources of smoke is the forcing of boilers of deficient capacity; this practice cannot be too forcibly condemned, as it is wasteful in the extreme and exceedingly dangerous.

The following are a few succinct remarks by Mr. Anderson, of Glasgow, on consumption of fuel and prevention of smoke.

"Stokers should understand that they are not to make a business of stoking, but to leave it off entirely, excepting only when preparing to clear out the grate from clinkers and rubbish, which requires to be done generally three or four times a day with average qualities of coal—convenient times being chosen for the purpose, when there is the least demand for steam.

"A fireman's business is first to see, before the furnace door is opened, that no coal is left in the heap ready for going on bigger than a man's fist, and that any small coal or slack is wetted, or at least damp, and that there is always a little water in the ashpit.

"Then begin by charging into the further end of the furnace, reaching to about one-third the length of the grate from the bridge, as rapidly as possible, from a dozen to twenty or thirty spadesful of coals, until they form a bank reaching nearly or quite up to the top of the bridge, and then shut the furnace door until the other fires, if there are any, are served in the same way.

"In firing up, throw the coals over the rest of the grate, by scattering them evenly from side to side, but thinner at the front near the dead plate than at the middle or back.

"In this manner keep the fuel moderately thick and level across the bars, but always thicker at the back than at the front; not by pushing the fuel in, but by throwing coals exactly where and when they are wanted. Never for a moment leave any portion of the bars uncovered.

"In replenishing the fire, take every opportunity of keeping up the bank of fuel at the bridge, by recharging it at one side at a time.

"Whenever this bank is burnt entirely through or low, and also when the fire is in a low state generally, take the rake and draw back the half-burnt fuel twelve or eighteen inches from the bridge, and recharge fresh coal into its place upon the fire bars as at first."

If the chimney is not provided with a damper, the defect should be remedied.

A moveable damper should be fixed in the flue close to the chimney, provided with a regulating chain accessible at the stoke-hole.

When the draught is excessive, the pressure of the cold air forcing itself through the fire will produce smoke, and it is certain that an excessive chimney draught is one of the commonest causes of smoky chimneys.

An intelligent stoker will by observation soon know how to regulate his chimney damper so as to obtain just the chimney draught to produce the flow of air necessary for perfect combustion. The furnace door should be kept constantly closed. After the fire is properly lighted, the safety valves should be raised a little, to allow the air in the boiler to escape.

If steam is formed too rapidly, the chimney draught should be decreased by lowering the chimney damper.

The water in the boiler should be constantly kept at a normal height by allowing the feed water to enter steadily and constantly, so as to sufficiently replenish the water evaporated. When the water commences to fall abnormally, the precautions mentioned on the following pages for enginemen should be attended to.

If a boiler foams or primes it is because it has either insufficient steam room or because the feed water is dirty or greasy; foaming often occurs with new boilers because the feed water is dirty or greasy, and also owing to the tar forming the coating of the boiler plates, but after the boilers have been in use for some time this will disappear. When a boiler primes it is almost impossible to maintain the water at a uniform and constant level, and when much water is carried over with the steam from absence of sufficient steam room, the water thus carried to the cylinder is a constant source of danger to the engine. When the priming is caused by insufficient steam room, it may be overcome by increasing the steam pressure and throttling it down to the ordinary working pressure in the cylinder, a process which requires extreme care. But the best plan, and only effectual one, is to provide more steam room, either by adding steam driers or domes to the boilers, or new and larger boilers. When the priming is the result of dirt and grease, the water should be blown off frequently to clear the boiler, which should moreover be cleaned as often as practicable; before blowing off, the water level should be raised by increasing the feed supply and then blown down to the normal level.

When the engine is in action it will have been noticed that the water increases in height, and falls when the engine is stopped; the stoker should ascertain the actual increase of the height of the water in such a case, so that he can make the necessary allowance, in order to have a proper quantity of water in the boiler when the engine is stopped.

The stoker should constantly examine and test the valves and steam gauges; grease and other solids are often precipitated in the gauges, and choke them; they should therefore be frequently blown out.

A cord should be attached to the safety valve so as to be easy of access to the fireman in the stoke-hole, so that he may not only be able instantly to open the valve should danger arise, but he can also ascertain if the valve sticks to its seat.

## CHAPTER XIX.

### THE MANAGEMENT AND SAFETY OF STEAM BOILERS AND ENGINES.

THE safety of an engine almost entirely depends on the engineman. Manufacturers should entrust the care of their prime motors only to careful, steady, reliable, and intelligent men. A great deal depends on the engineman's system of working; a regular routine is the best, as it often prevents dangerous indiscretions through forgetfulness.

After the fire is properly lighted, the engineman should see that the safety valves are slightly raised, so as to allow the air in the boiler to escape. He should also examine the various adjustments of the safety appliances connected with the boiler, so as to check the work of the fireman. He should now examine the valves of the engine and make the necessary adjustments, screwing up the stuffing boxes, joints, and glands, and open the cylinder cocks for the escape of air and condensed water.

After the steam is raised to sufficient pressure, the stop-valve should be gently opened.

In commencing the motion of smaller engines, a great difficulty is experienced when the crank is at the position known as dead centre, and a most dangerous practice is often resorted to in order to move the crank past the centre; the engineman applies a bar between the arms of the flywheel to act as a lever to produce motion: numerous and terrible accidents have occurred from this practice. By a little care at the time the engine is stopped, the crank could be arrested at or near the position best suited for restarting. As soon as the engine is started the engineman should examine the bearings and lubricate where required, keeping a constant supervision over the furnaces, the water and steam supply, and the engine and shafting.

If steam is produced too rapidly, the draught of the fire should be decreased by lowering the damper or closing the ashpit doors. He should see that the water in the boiler is kept at a uniform level; this can be done if the feed water is allowed to enter the boiler steadily and constantly, so as to replenish the water as soon as evaporated. When the water commences to fall too quickly its cause should at once be ascertained. The engineman should first examine the pump; he can tell the condition of its action by listening to the sound of the check valve. When the temperature of the water is excessively high, a pump (unless especially adapted) will not work; if it refuses from this cause, the temperature should be immediately reduced. Common causes of inefficient working of the pump are defective packing or when the valves are not opened.

If the pump is defective it should be immediately remedied, otherwise disaster will inevitably follow. If after examining the pump, and it is found to be all right, a leakage will probably be the cause of the falling water. If a leak is found, it can occasionally be temporarily repaired until stopping time by plugging or by increasing the action of the pump to compensate for the leakage. If the defect cannot be remedied, the chimney damper should be lowered and the ashpit door closed, and the boiler relieved from pressure as soon as possible.

Steam engines should always be isolated, and all the parts in motion, where practicable, should be fenced off. The cranks, piston, and connecting rods, valve spindles and eccentrics, should have special arrangements of lubrication, so as not to require any lubrication during action, and it should be the engineman's special duty to see that the lubricating vessels are replenished before the engine commences work.

be removed, and Portland cement and ground fireclay mixed in equal proportions should be used in its place. Lime promotes corrosive action, and its use, therefore, should be avoided. A boiler should never be allowed to remain unheated, as moist air is very active in producing corrosion. If, however, there is sufficient heat to prevent the aqueous vapour contained in the air from condensing on the boiler, corrosion will not occur. Another prolific source of boiler explosions is the generally damp state of the boiler foundation. The moisture from the undrained subsoil ascends by capillary attraction into and through the walls of the boiler setting, and produces active corrosive action where least suspected. Boiler foundations should therefore be thoroughly drained.

It is to be hoped that in the future all new boiler plates will be coated with magnetic oxide, either by Professor Barff's or Mr. Bower's process. The magnetic-oxide coating is imperishable, and its application would therefore remove the principal source of the dangers at present unfortunately connected with the application of steam power.

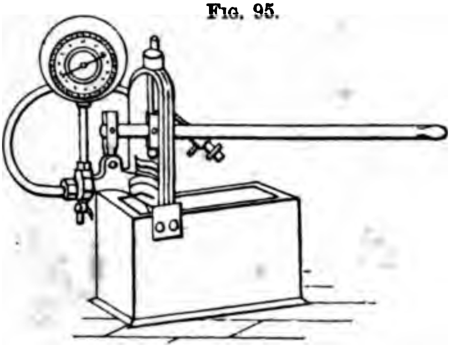
### *Fracture of Plate and Angle Irons.*

Both these defects are the common results of bad workmanship or materials, although they may be the result of the constant vibration which boiler plates are subjected to. It is an established truism that the fibrous structure of wrought iron undergoes a gradual transition when subjected to a constant vibration for a series of years. The elongated molecules resume their original state as in cast iron, and the wrought iron eventually becomes little better than cast iron.

A constant and close inspection may save many disasters from this cause, but the only reliably safe method of ascertaining the true state of a boiler, is to test the boiler by hydraulic pressure; this should be done at least once a month under the supervision of a responsible person.

A hydraulic boiler testing apparatus has been devised by Mr. W. H. Bailey, of Salford (see Fig. 95), which is cheap, substantial, and effective; the price is 10*l.* *Note.*—Boilers should never be tested any higher than one-third more than the nominal working pressure.

FIG. 95.



## *Safety Valves out of Order or Overloaded.*

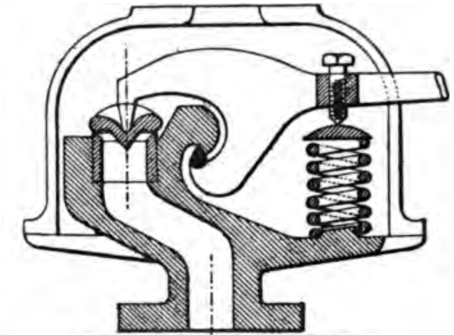
This is one of the most prolific of the causes producing explosions. The lever valves are either allowed to remain untouched until active oxidation fastens the valve to its seat, or in order to obtain excessive pressure the weight is moved too far on the lever, thus extending the pressure limit to a point which the strength of the plates is not calculated to bear. A safety valve should be as simple as possible in construction, with few joints or pins.

The maximum limit of its pressure range should be considerably under the safe working strength of the boiler plates.

All the joints, seatings, pins, and other points in contact should be of incorrodible material.

Figs. 96 and 97 represent Schmid's safety valve, a really good form, and unpatented. It is of that class in which the pressure tending to keep the valve to its seat becomes less as the pressure increases, thus ensuring free and an increasing passage for the steam. The valve should be coated with magnetic oxide, the seats and pins nickel plated.

Fig. 96.



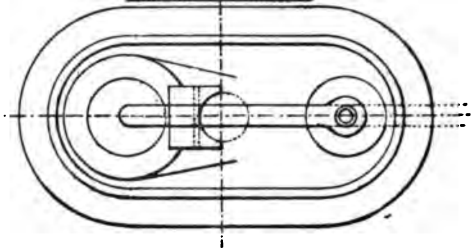
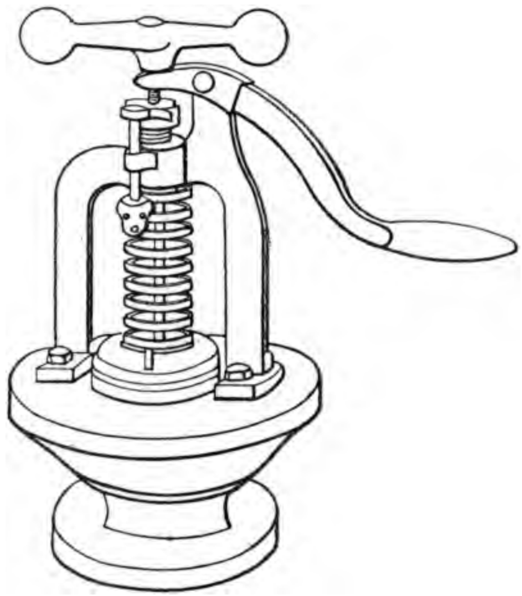


Fig. 97.

A good and simple form of valve is that of Bailey and Ashcroft's, known as the pop safety valve (see Fig. 98). The seat of the valve being of nickel bronze, as hard as steel, and as nonoxidisable as gold, corrosion is prevented. It lifts higher from its seat than any other form of valve, and discharges as much as five valves of the ordinary construction, and when it discharges the great rise of the valve produces a considerable noise, hence its name, pop valve.

The valve may be moved whilst actually under pressure to test its condition.

Fig. 98.



It can be locked up and therefore cannot be tampered with.

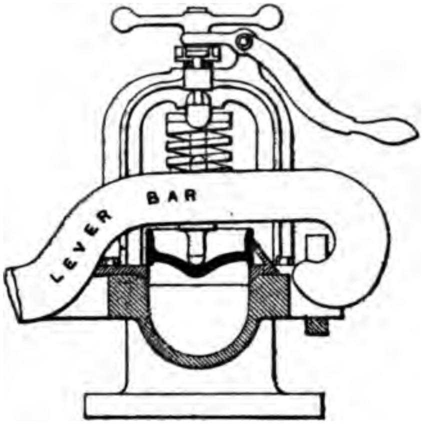
There are no levers, pins, or joints, to interfere with its free action.

Fig. 99 represents a government pattern safety valve as arranged by Messrs. Bailey and Ashcroft. It consists of one lever safety valve, one spring safety valve, locked-up test lever, and rotary spindles for testing; the spring and seats nickel plated.

### *Pressure Gauges out of Order.*

Neglect in blowing out, testing, and cleaning the gauges soon destroys their efficiency. The sulphurous emanations from the stoke-hole (unless they are well ventilated) soon corrode the working parts of the dial, and the tube eventually becomes choked. The working parts should constantly be kept clean. Bourdon's gauge as improved by Bailey is one of the most perfect forms of gauges.

FIG. 99.



The case is solid gun-metal, and the syphon of registered pattern, by which a test gauge may be attached and the accuracy of the gauge determined; a danger hand is fixed to the dial to plainly define the maximum limit of pressure. The danger hand can be locked to its position by the masters, so as to refute any false evidence which might be given by the stoker or other person in charge of the boiler, in case of accident and Government inquiry.

Blancke's steel plate gauge, with the dial protected by a wire guard, is also an admirable contrivance.

### *Water Gauges out of Order or Fixed too Low.*

The fixing of the water gauges too low is a very common defect.

The gauges should be placed at least six inches above the top of the flues, and owing to the constant danger of the glass recording untruthfully, an additional check gauge glass should be fixed to all boilers.

FIG. 100.

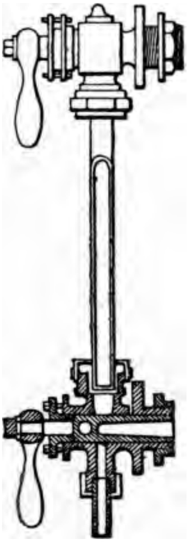
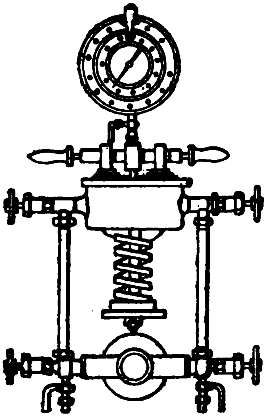


FIG. 101.



Howat's patent gauge glasses are a great improvement on the ordinary form. Bailey has also introduced a new and excellent form of gauge cock, the chief feature in which consists of a revolving scraper which is actuated every time the bottom cock is opened and closed, thereby removing the sediment and preventing a false indication of the state of the water supply. See Fig. 100.

The gauge cocks should be constantly examined and the sediment blown out.

A perfect combination of boiler safety appliances is shown in Fig. 101. Spring valve coated with nickel to prevent oxidation, improved scavenging gauge cock, and steam gauge with danger hand.

This arrangement is known as the Bailey-Ramsbottom.

The double water gauge made by C. W. J. Blancke, of Merseburgh and Manchester, is also an admirable contrivance.

### *Boilers Damaged by Overheating in consequence of Deposit.*

Dr. M. J. G. Rogers, of Madison, U.S., lucidly describes the evil properties of boiler incrustations in a paper published a few years ago. He estimates the conducting power of incrustations in comparison with iron as 1 to 37·5; a scale of $\frac{1}{16}$ inch thick therefore requires 15 per cent. more fuel; a scale of $\frac{1}{4}$ inch thick requires 60 per cent., and one $\frac{1}{2}$ inch thick 150 per cent. more fuel. In order to produce steam having a pressure of 90 lbs., water must be heated to about 320° Fahrenheit, and with a clean and rationally devised boiler this can be done with $\frac{1}{4}$-inch thick plates by maintaining a temperature of 325° Fahrenheit. If, however, a $\frac{1}{2}$-inch scale intervenes between the shell and the water, a temperature of 700° Fahrenheit will be required, and as it will be seen by referring to page 200 the strength of iron decreases in proportion to its increase of heat, the dangers of incrustation will at once be apparent. There are hundreds of anti-incrustation agents in the market, but with few exceptions they are practically useless, among them tannic acid and caustic soda appear to be the best.

Lately Mr. G. E. Davies, of Manchester, has introduced a remedy which he has tried for fifteen months with great success. The agent is tribasic phosphate soda, which has the property of absorbing the free carbonic acid in water, and by its action on sulphate of lime forms phosphate of lime and sulphate of soda.

These deposits do not harden, and they do not adhere to the boiler plates, and can be blown off, rendering the chipping hammer unnecessary.

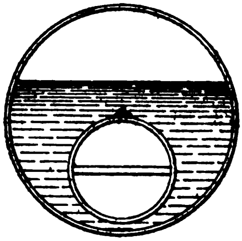
Lately, at a meeting of the Manchester Geological Society, Mr. Peter Spencer stated that no boiler on his works had been chipped for the last fifteen years. This was simply due to his keeping the water supplied to the boilers alkaline, by adding, from time to time, a little carbonate of soda or soda ash.

### *Boilers Damaged in consequence of Deficiency of Water.*

On referring to page 200 it will be seen how greatly the strength of iron decreases when subjected to heat: the great danger of allowing the water to fall so low as to expose the crown of the flue to the heat of the furnace will therefore be evident.

Many ingenious low-water detectors have been invented; among them the fusible plug arrangement, which consists in fixing a plug formed of an easily fusible alloy on the crown of the boiler flue (see Fig. 102). Should the water fall too low, the heat of the fire fuses the plug, and the steam rushing into the furnace extinguishes the fire.

Fig. 102.



Fusible plugs as ordinarily formed are anything but reliable. The one invented by Bailey, of Salford, is, however, a great improvement on the ordinary form, and consists of a fusible metal disc, in the centre of which is a disc of copper; should the water fall to a dangerous level, the fire causes the copper disc to be blown through the fusible metal, and the fire is extinguished.

A most admirable and decidedly the best contrivance for giving an alarm when the water is falling to a dangerous level, is shown by Figs. 103 and 104, and known as

Fig. 103.

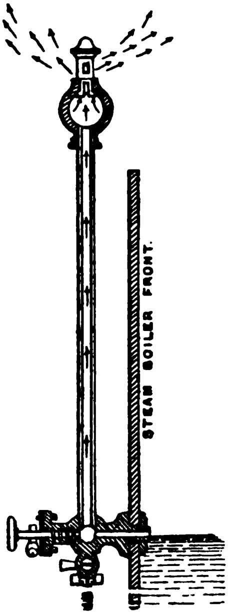
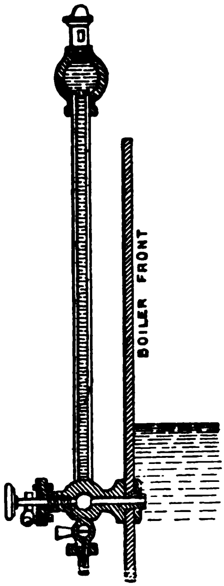


Fig. 104.



the Ashcroft low-water detector and alarm. The action of this instrument depends on a fusible plug formed of an alloy that melts at the boiling-point of water, placed at the summit of a brass ball which surmounts a tube which has a junction with the boiler at the lowest safe water-level. Should the water in the boiler fall below this level, the steam, passing up the tube and filling the ball, melts the fusible plug and blows the whistle, creating an alarm.

Blancke's low-water alarm is in principle similar to that of Ashcroft's. One great advantage of Ashcroft's and Blancke's low-water detectors over the ordinary fusible plug, is the fact that to renew the latter the boiler has to be emptied, but in the former the plug can be renewed without any trouble.

The following succinct remarks anent the cause of explosions of high-pressure boilers, by S. W. Macdonald, are worth repeating.

"The explosion of high-pressure steam boilers almost invariably occurs at the starting of the engine, and is a result of the disturbance which takes place in the boiler whenever the steam begins to be drawn off; or in other words, when the boiler and its contents are passing from a state of quiescence to one of activity. In the case of a stationary boiler, as the steam is raised, there is no movement of its contents beyond ebullition, which almost ceases as the pressure increases, and then the water next the flues becomes surcharged with heat; but when the engine is started, agitation is produced in the contents of the boiler and friction in the body of the water, causing a rapid liberation of steam, and a sudden momentary increase in the pressure. These are the conditions most favourable for producing an explosion, and hence the frequency of such a dreadful catastrophe at such a time. At a moderately high temperature, heat decomposes water, and may impart to it a most destructive explosive power, akin in its nature to that of dynamite; as for instance, when through excess of pressure a boiler bursts, and the water strikes the incandescent fuel in the furnace, the intensity and force of the explosion is terrible, and invariably most destructive.

"To guard against a dangerous accumulation of heat during the raising of steam, or when the engine is not going, the discharge safety valve should be partially opened or moved occasionally to let off steam, in order to prevent over-pressure.

"To check the pressure, every boiler should have a water safety valve, through which the water would overflow with over-pressure, and also blow off steam when the water gets too low, and, in addition, a small pressure steam valve to indicate when the steam is right.

"*Note.*—The safety valve should not be kept constantly closed until the engine is going."

# PART V.

## THE ORIGIN OF CONFLAGRATIONS AND THEIR PREVENTION.

## CHAPTER XXI.

### GENERAL CAUSES OF FIRE.

1. Defective lighting arrangements.
2. Careless use of igniting appliances.
3. Defective lubrication.
4. Imperfect storage arrangements.
5. Spontaneous combustion.
6. Bad heating arrangements.
7. Incendiarism.
8. Faulty construction.
9. Explosions of mineral oils.

1. DEFECTIVE gas-lighting arrangements are a prolific cause of fire.

The jets are often placed in dangerous proximity to combustible materials. In textile manufactories many fires have originated from the fluff or waste (which may have accumulated in some portion of the roof) falling on the gas jets: ventilation and cleanliness alone will prevent these fluffy accumulations. The gas mains are often fixed in inaccessible positions, and exposed to atmospheric influences, with the result that oxidation eventually produces leakage—the gas insidiously escapes, accumulates, and explodes.

The evaporation from the water-joint in the telescopic slides of gas chandeliers causes many explosions.

2. In mills and warehouses a very common and dangerous practice is that of persons searching for goods or other articles with lighted tapers or matches which are thrown on the floor where they lie smouldering—

often enough flickering into a flame—producing disastrous results.

Exhaustion by overwork is sometimes an indirect cause of fire; the men become sleepy from a prolonged taxation of their energies, and either forget or from fatigue neglect to extinguish the fires and lights.

3. To defective lubrication may be traced some of the most destructive conflagrations which periodically occur in the great hives of industry, especially in cotton and woollen mills.

The shafting becomes red hot from absence of lubrication, ignites some of the fluffy particles of cotton, wool, &c., in the air, and the fire spreads like lightning.

4. Improper storage of dangerous goods is another source of danger.

Oils are comparatively safe if nothing else is stored with them.

If sulphur and saltpetre are stored together at high temperatures, they are liable to explode; if stored alone they are comparatively harmless. A fire occurred in a warehouse in St. Katharine's Docks, and owing to the ignited spirits (which the warehouse contained) flowing through the doorways between other warehouses, the fire rapidly extended. This occurrence points to the desirability of having all door thresholds of warehouses slightly raised.

The following is a list of dangerous goods in their relative order.

The most dangerous are gun-cotton, dynamite, gunpowder, nitro-glycerine, petroleum, benzoline, phosphorus, and all illuminating oils below the legal ignition point of 100°, imposed by Act of Parliament.

All the above-mentioned goods ignite at or near the normal temperature, and cannot be extinguished by water alone.

In the next class of dangerous goods may be comprised pyrites, vegetable and animal oils and fats, beeswax, all illuminating oils with an ignition point above 130°, lubricating grease, pitch, bitumen, paraffin, wax, and candles.

In the next class—less dangerous—may be comprised coals, charcoal and other fuel, fabrics composed of vegetable fibres, cotton, flax, hemp, and jute.

5. Spontaneous combustion is the cause of many fires.

According to M. Chevallier, the different matters most liable to spontaneous ignition are:

1. Heaps of damp wheat.
2. Ground coffee.
3. Malt.
4. Scorched chicory.
5. Scorched rye.
6. Heaps of peat ashes.
7. Heaps of burnt cocoa.
8. Covered bones.
9. Wet sawdust.
10. Flour from grain.

Old cordage, linseed oil cakes, mixtures of vegetables which have been boiled with greasy substances and retain them, tobacco in heaps, rotten wood, damp cotton under pressure of weight, cotton oil waste, sulphuric and nitric acids in contact with combustible matter such as straw, wool, essential oils, &c.

According to Tardieu, quick lime has given rise to spontaneous combustion.

A heap of quick lime was in a farmyard, near a stable; the urine from the horses having moistened the lime, enough heat was generated to set fire to some dried leaves, and the fire spread elsewhere.

The most dangerous collections of matter are heaps of greasy rags, wools, bits of cotton.

Experiments have shown that a mixture of soot, oil, and rags is more liable to spontaneous combustion than any mixture commonly met with.

### *The Theory of Spontaneous Combustion.*

All vegetables in actual life absorb heat; it need not, therefore, be a matter of surprise that bodies containing so much stored up heat as do vegetables of all kinds, more particularly greasy or oily rags, sawdust, cotton waste, and all materials of vegetable origin, should be liable to spontaneous combustion. In the action of decomposition, when the materials are gradually returning to their original elements of carbon, nitrogen, &c., the heat stored up is set free, and spontaneous combustion is the result. It is clear that the production of heat will be in proportion to the bulk of the material, and therefore the danger of spontaneous combustion increases directly as the bulk.

6. Bad heating arrangements are often causes of fires.

If steam pipes are constantly in close contact with timber they will eventually desiccate it, and render it liable to fire spontaneously.

Hot air heated by a red-hot cockle will occasionally heat the pipes to a dangerous extent, and they should, therefore, not be placed in contact with timber. Hot-water pipes are a common source of fire when under excessive pressure.

7. Incendiarism (see page 160).

8. Faulty construction.

Malconstruction of chimney flues is a frequent cause of fire.

Faulty construction is most common in those buildings which have been subjected to alterations, and where flues have been made, new fireplaces, stoves, and timber fixed in ignorance of original constructional arrangements.

9. Explosions of mineral oils arising from the vapour given off by them; and in considering the dangerous character of oils, too much consequence cannot be placed

on their igniting point, e. g. the temperature at which oils give off vapour. The lower the temperature at which oils give off vapour, the greater the risk of explosion.

No oil produced by distillation from coal, shale, petroleum, rock oil, Rangoon oil, and other bituminous substances, and used for illuminating purposes, should be sold for such purposes with an igniting point under 110° Fahr. Many lives have been lost by the explosion of oils having low igniting points.

### *Explosions in Flour Mills.*

When flour is mixed with bran heated to 450° Fahr. inflammable gases are given off, and occasionally produce explosions, and the dry flour which is disseminated in the air of unventilated flour mills is instantly ignited, and the mill is set on fire. This is a common origin of fires in flour mills.

### *Solar Heat.*

A case occurred in Scotland where a fire originated among flax, owing to concentration of solar heat rays upon the flax by a bull's-eye on the glass of one of the windows. A fire also occurred at Grenoble, France, which was traced to the same cause.

## CHAPTER XXII.

### PREVENTION OF FIRE.

The following is a brief summary of the existing legislative provisions for the protection of life and property from fire. From the fact that the following Acts do not enforce the construction of buildings which will completely resist fire, they have had but little influence in decreasing their number and magnitude:—

1. "The Towns Improvement Clauses Act, 1847," 10 & 11 Vict. c. 34, which contains provisions regulating the erection of buildings with the view of preventing fires by means of party-walls carried through and above the roofs, and the construction of all walls and roofs of incombustible materials, and also supplying and maintaining fire-plugs.

2. "The Waterworks Clauses Act, 1847," 10 Vict. c. 18, which contemplates the provision of a constant supply of water for domestic purposes and for the purpose of extinguishing fires at such a pressure as to make the water reach the top storey of the highest house within the town, and for the fixing of fire-plugs in the mains.

3. "The Local Government Act, 1858," superseding the "Light and Watching Act" of 1833, and incorporating some of the provisions of the "Towns Improvement Act, 1847."

4. "The General Police and Improvements (Scotland) Act, 1862," 25 & 26 Vict. c. 101, which contains provisions with the view of preventing the spreading of fires, and for the purchase and keeping up of fire-engines, hose, buckets, &c.

5. "The Gunpowder Act of 1860," 23 & 24 Vict. c. 39.

6. "An Act for the Safe Keeping of Petroleum, 1862," 25 & 26 Vict. c. 66.

7. "An Act for the Amendment of the Law with respect to the Carriage and Deposit of Dangerous Goods, 1866," 29 & 30 Vict. c. 69.

And a series of local acts conferred on the principal provincial towns.

### *Statutory Penalties for Incendiarism.*

Setting fire to a house wilfully is punishable with penal servitude for life.

If death is occasioned by the fire, the offence is capital, and punishable by death.

Setting fire to a building with intent to defraud is a felony, punishable with penal servitude for life.

Incendiary attempts are punishable with penal servitude for fifteen years.

In the remarks on the origin of conflagrations, the most general causes producing fire have been pointed out.

*Gas-lighting Arrangements.*—All gas mains should be placed in accessible positions, and the coatings for the prevention of corrosion should be frequently renewed; careful supervision should be given to the gas-lighting arrangements; the whole of the private mains should be tested periodically with Bailey's tester.

All gas jets liable to contact with inflammable materials should be covered with wire guards.

An intelligent and sober workman should be entrusted with the lighting arrangements, and no other person should be allowed to interfere with them.

*Igniting Appliances.*—The greatest caution should be exercised in the use of igniting appliances. In large factories and workshops a responsible person should have the care of all the gas jets, and penalties should be enforced which would prevent any but the responsible person from igniting any of them.

The matches of Bryant and May are very safe, but Mr. Sankey of Manchester has lately introduced a match superior to any for safety. The match, besides possessing the qualities of the ordinary safety-match, has in addition the following advantages:—In burning, the head does not drop off, nor the wood continue to glow with a red heat; immediately the flame is out all danger is removed, and the match may be allowed to fall anywhere, or may be held by the charred end until entirely consumed, and will not burn or soil the fingers.

*Lubrication, &c.*—One of the principal causes of fire is certainly the overheating of the bearings from absence of lubrication. The coefficients of expansion and contraction of brass or gun-metal (the materials most commonly used for bearings) are greater than the material forming the shafting, usually wrought iron or steel; and again, brass and gun-metal are greater conductors of heat than cast iron; therefore, in proportion as the heat increases by the friction, the brasses clutch the shafting tighter, and the shafting soon becomes heated to a dangerous extent.

All bearings should be guarded with a simple cover of tinplate, so that in the event of the shafting becoming red hot, there will be no danger of fire; they should be further provided with a hot-bearing indicator.

Alley's Hot-bearing Indicator is shown in Figs. 105 and 106.

This ingenious instrument consists of a bell A, which is struck by the hammer B when the bearing becomes heated sufficiently to melt a composition (consisting of grease or other material that will melt at a low temperature) placed in the tube C. This tube is placed in a hole in the cap of the bearing in such a manner that the lower end rests on the shaft D; on one side at the bottom the tube is cut away sufficiently to allow the plug of grease to be inserted when the handle is up. The hammer is attached to a spindle, which a spring tends constantly to press down upon the plug of grease. The upper portion of the spindle is provided with a rack, the teeth of which take into a pinion connected by means of a ratchet-wheel to a striking wheel F, which revolving, alternately draws down and releases the pallet G, to which the hammer of the bell is attached.

The spring forces the spindle down as fast as the grease liquefies and runs out at the orifice, thus setting in motion the pinion and wheel F, and striking the bell with slow or rapid repetitions, according to the temperature of the bearing.

It will also be seen that while the indicator draws attention to the state of the bearing, so long as the grease lasts, it prevents the bearing from becoming seriously

FIG. 105.

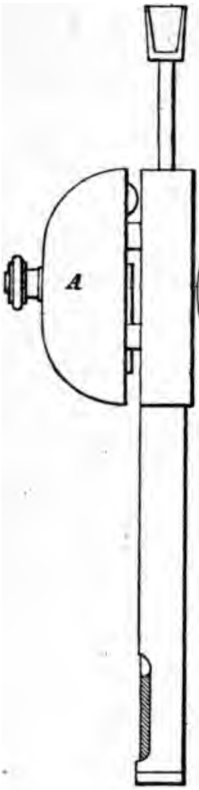
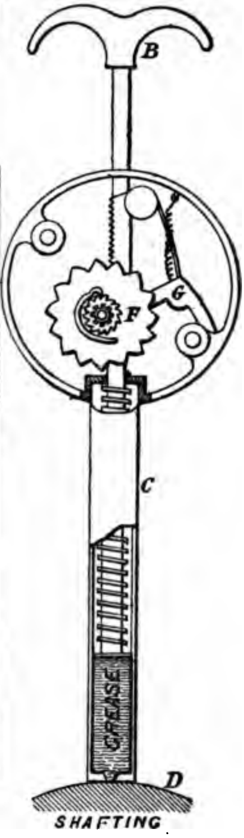


FIG. 106.



damaged, at the same time making signals sufficiently clear and distinct to attract the attention of all but the most careless attendants.

It is simple in construction, and not liable to get out of order.

Too much importance cannot be attached to the adjustment of bearings. The bearing surface of the shafting should be thoroughly even, else there is a greater tendency to irregular lubrication and overheating. For hangers, Carter's patent self-adjusting, self-lubricating hangers cannot be too highly recommended; they almost entirely eliminate all tendency to overheating.

*Storage Arrangements.*—The storage arrangements for the reception of combustible materials deserve the most serious consideration. The walls and floors should be constructed so as to be fire-resisting.

Warehouses should never exceed in extent the limit set by the "Metropolitan Building Act," viz. 216,000 cubic feet. If the warehouses are subdivided into areas of moderate size, should a fire occur, the difficulty of the extinction will be proportionately lessened.

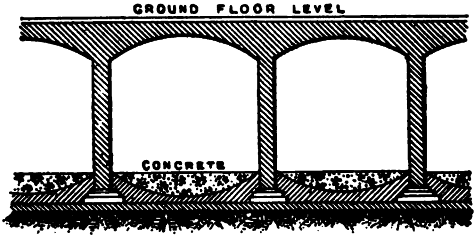
In the erection of warehouses to contain petroleum and other highly inflammable liquids, the following is a good principle, viz. the utilisation of detached cellars, each compartment say about 15 feet long by 30 feet wide, and built entirely of concrete. (See Fig. 107.)

In the storage of goods liable to spontaneous combustion, excessive bulk should be avoided. Observe the importance of not storing goods too near the ceiling; a fire originating and spreading in such close contact would prove a dangerous test to the most perfect fire-resisting floor.

The goods should never be stored to a greater height than 6 feet from the ceiling.

Accumulations of waste should never be allowed; a separate and detached compartment should be provided for the reception of all waste. All useless crevices and holes in which dust is liable to accumulate, should be filled up. It may be again noted here that, when the air is impregnated with dust from textiles, the slightest spark will sometimes instantly ignite the dust, and the fire will spread like lightning. Efficient ventilation will alone remedy this danger, by the removal of the dust.

FIG. 107.



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## CHAPTER XXIII.

### SELF-ACTING FIRE ALARMS.

ONE of the first arrangements of mechanically signalling the outbreak of fire, was that patented by Mr. Greenhalgh in 1862, No. 1920, which consists of a self-acting alarum, combined with a water or steam valve; a weight is suspended by a cord of gutta-percha or other material which will quickly ignite. A lever communicates with, and when struck operates, a stop-valve attached to a system of pipes containing steam, and furnished with branches extending in all directions within a building where a fire is likely to occur. Instead of a weight, the reaction of springs may be employed to operate the valve, when the cord is burnt through.

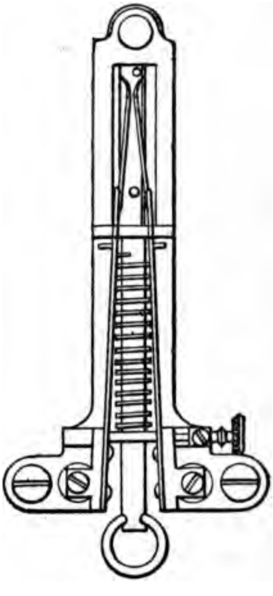
This arrangement has had only very few applications.

Later on, inventors have exclusively occupied themselves in devising a self-acting process of alarm, with electricity as the motor. It would be useless to enumerate the many devices which have been made, having for their principle the completion of an electric circle by means of the expansion or dilation of a metallic rod, under the influence of the elevation of temperature produced by the heat of an outbreak of fire. These arrangements, although superior to those purely mechanical, have nevertheless displayed serious drawbacks, owing to the fact that as the instruments were not brought into requisition, except in circumstances purely accidental, and at times of very wide intervals; the points of contact of the electric circle became oxidised or rusty, to the extent of destroying conductivity and rendering them utterly useless when required. This defect occurs notably when mercurial apparatus is employed: even when the points of contact have been made with inoxidisable metals the same disastrous effect has occurred, owing to the dust, spiders' webs, insect excrements, &c., which accumulate. It is therefore necessary to keep the instruments continually clean if they are to be at all useful; but this remedy, by reason of the exceptionally rare occurrence of their use, is liable to become entirely overlooked.

For these reasons a new basis has been adopted for the solution of the problem of providing an efficient electrical alarm. An English electrician has invented the following arrangement. The electric circuit is constantly complete; a metallic bar is placed in such a way that at the slightest increase of temperature it separates from the point of contact, and thus breaks the circuit and sets in motion a hammer which loudly strikes a sonorous bell.

This instrument does not present the same inconveniences as the preceding ones, but it is subject to numerous expenses in repair, especially in the maintenance of the battery piles, the employment of which is continuous; and then it necessitates a special installation of indicator tables and distinct telegraphic apparatus, in order that it may be known where the fire has broken out.

FIG. 108.



M. de Gaulin, of Paris, has endeavoured in an apparatus he has invented (see Fig. 108), to obviate all the inconveniences already enumerated, without the corresponding expenses. The apparatus may replace the ordinary electric knobs or buttons in such a way that it can be utilised at once for various daily uses, such as the opening of doors, signalling, &c. In this action the current is set in motion by the person pulling the ring, but in the case of fire breaking out, it rings automatically: a plate of metal, which is fixed to the wall or any woodwork near the ceiling by means of three screws, receives the electric wires below. Two metallic guides are placed at the lower part of the apparatus, and to which, sensitive bars are fixed at one of their lower extremities, in such a way as to place them in an upright position and forming a very acute angle with each other. The sensitive bars are prolonged at the summit and only kept in place by a thin steel guide.

At the slightest increase of temperature the thin and sensitive steel bars come in contact with each other at their highest extremities, establishing an electrical current. A sliding bar moving vertically on the base plate is fixed behind the rods, terminating at its lower extremity by a ring, and at its summit by a metallic index, arranged in such a way as to come in contact, when desired, with the sensitive bars at their summit, and thus bring the two poles in contact. This sliding movement is obtained by pulling the cord attached to the ring as in the ordinary method of bell hanging.

A steel coil spring lifts the sliding bar to its place, interrupting the flow of the electric current; the apparatus is then in a normal position, the sensitive bars and index being separated in such a way that the electric current, which is located in the right-hand bar and plate, is forcibly kept prisoner, and cannot escape except by the left-hand bar, which is isolated from the plate by means of an ebonite cylinder which surrounds the metallic guides, and to which it is fixed. The apparatus can be set in action by two means: first, by the action of heat, which bends the sensitive bars establishing the electric current, and sounds an alarm bell or whistle, which continues as long as the heat exists. Secondly, by the use of the handle, or cord attached to the handle, which being pulled will bring the index between the two bars and thus establish the current. The action of pulling, however violent, cannot alter the sensibility of the metallic bars, for the reason that the inventor has taken the precaution to furnish them with very flexible steel prolongations. All the system is established with a solidity, such that the most energetic pull may break the cord attached to the ring, but cannot in any case injure the sensibility of the machine.

The sensibility of the machine is rendered variable by means of a set screw placed upon the right, and outside of the protecting ebonite envelope. The distance between the two sensitive bars can be varied by the set screw.

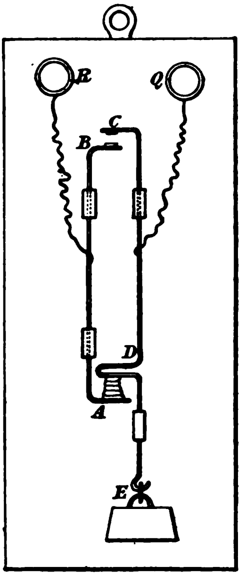
A needle fixed at the head of the set screw described, passes round a dial plate upon the lateral face of the guide, graduated by thermometrical comparison.

One has only to set the needle upon the division corresponding to the temperature at which it is desired the automatical action shall come into play.

This instrument appears to fulfil all the conditions required to constitute a trustworthy alarm. Its principal point of superiority consists in the constant contact to which it is or may be submitted by daily usage.

From the moment that the current passes and sounds the bell, one can be certain the instrument is in good order, and will act in an equally efficient way in case of fire. Any ordinary battery will suffice, and considering the increased application of electrical inventions, telephone, telegraph, electric light, &c., it is hoped that this valuable instrument may find a place in the rooms of every factory. The price of the instrument is about 10*s.*: it can be obtained at MM. Ch. Mildé Fils, 3, Rue de Monceau, Paris.

FIG. 109.



Another simple form of electrical fire alarm is shown in Fig. 109. It consists of two bent metal stems A B and C D, which are put into connection by means of the terminals Q R with a voltaic battery and an electric alarm bell: at B and C two platinum contact studs are fixed on the stems, and these are kept apart by a piece of common suet, tallow, or grease, placed between the stems at their lower parts A D. When the temperature of the room increases (at the outbreak of fire) so much as to melt the tallow, the stem C D is pulled down by the small weight E, and the contact stud on C makes contact with the stud on B, thereby completing the electric current and ringing the alarm bell.

FIG. 110.

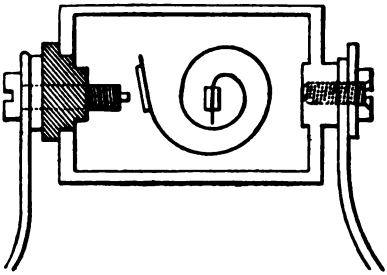


Fig. 110 represents Bright's self-acting fire-detective, consisting of a coil spring placed between contact studs. On a fire occurring, the heat expands the coil until it comes in contact with the studs and completes the circuit.

## CHAPTER XXIV.

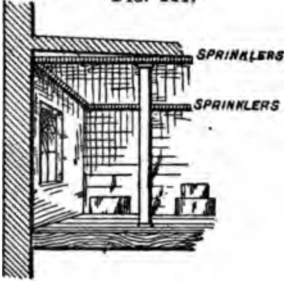
### PRIVATE FIRE-EXTINCTION APPLIANCES.

HOWEVER perfect the structural and other arrangements for the prevention and resistance of fire may be, there is still a possibility of an outbreak, and consequently it is advisable that in all factories, &c., some provision should be made for its immediate extinction. If proper arrangements are made, a fire, if attended to at its origin, can be immediately suppressed. The principal agents of extinction are water and steam.

### *Sprinkler Arrangement.*

At Lowell, U.S., millowners have co-operated for mutual benefit in providing arrangements for fire extinction. Each mill has a complete set of pumps and sprinklers—that is, a series of perforated metal pipes arranged along each room on the under side of the ceilings, so that when a pressure of water is let on, all the rooms are instantly deluged with water (see Fig. 111). Where public water mains are convenient, this sprinkler system can easily be applied, and if the water mains are under constant pressure, this plan is one of the very best that can be adopted. In some of the mills at Lowell, U.S., such provision is made that the water is turned into the sprinkler mains automatically when a fire occurs and the temperature of the rooms increases. At a certain point the mercury of a thermometer makes contact with a wire, and completes the circuit of an electric battery. The current set up flows through an electric magnet, and attracts an iron armature, which in turn actuates a detent and releases a wheel which opens or closes a stop-valve of the water main supplying the sprinklers. If public mains are not available, pumps will have to be provided to fill the sprinklers with water.

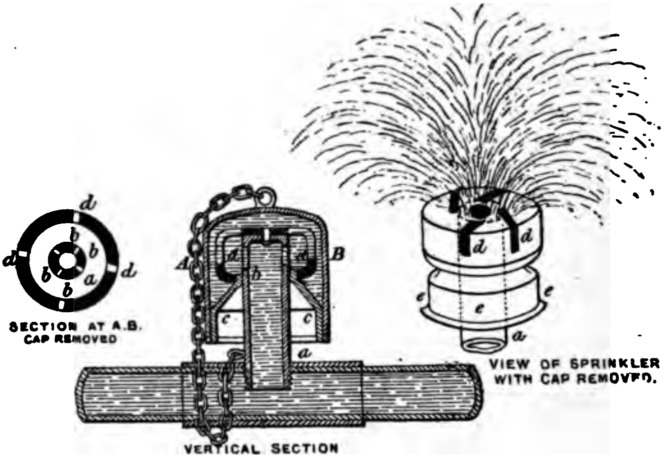
Fig. 111.



Very recently an improvement on the sprinkler system of fire extinction has been invented by Mr. H. S. Parmelee, of Newhaven, Connecticut, U.S. The invention which is termed Parmelee's patent automatic sprinkler, is shown by Figs. 112 and 113.

The apparatus, which is very small, about 2 inches × 3 inches, consists of an inner pipe *a* which can be screwed

FIG. 112. FIG. 113.



SECTION AT A.B. CAP REMOVED

VERTICAL SECTION PARMELEES AUTOMATIC SPRINKLER SHEWING ITS APPLICATION TO ORDINARY MAIN.

VIEW OF SPRINKLER WITH CAP REMOVED.

into the water mains, the head of the inner pipe is perforated with four slits *b*; to this inner pipe a loose hood *c* is connected with perforations *d*, arranged in such a way that the passage of the water under pressure through them, will make the hood revolve around the inner pipe with great rapidity, spreading the water in a spray over a larger or smaller area in direct proportion to the pressure of water on the main. At a water pressure of 60 lbs. to the square inch, the area covered by the fall of water from a single sprinkler will equal 113 square feet. The revolving hood is covered with a cap which is attached to the inner pipe at *e* by means of solder.

The action of the apparatus is as follows. The cap resists the pressure of the water, but should a fire occur and heat be generated sufficient to melt the solder, e. g. 160° Fahr., the cap is driven off by the pressure, and water issuing through the perforations in the hood, causes it to revolve, and the water is spread over a large area.

The manner of fixing the automatic sprinklers, which are formed entirely of brass, is as follows. The water mains are arranged as in the ordinary sprinkler system, either alongside the walls or in the centre of the rooms; from the water mains secondary mains project right and left at every 20 feet; from these secondary mains other branches are fixed also right and left at every 10 feet; at the termination of these branches, which are 5 feet long, elbows are attached, and into these the automatic sprinklers are screwed, pointing upwards, one sprinkler being provided for every 10 square feet.

The automatic character of this new system is a great improvement on the ordinary form, and the author, after witnessing a rather severe trial, was fully satisfied as to its great value, whenever a high and continuous pressure of water is obtainable.

### *Water-main, Hose, and Bucket Arrangements.*

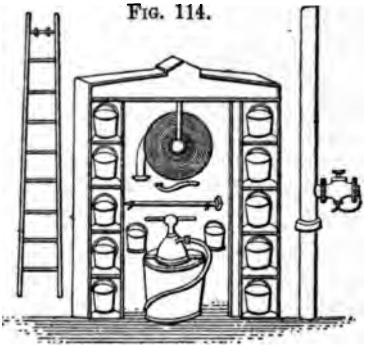
The secret of the success of this arrangement consists in having a definite position for the extinction apparatus. Many disastrous conflagrations have occurred in mills although extinction apparatus had been provided, but from absence of definite position they had been scattered and used for other purposes, and when the fire broke out they could not be found.

The value of the old adage, "A place for everything, and everything in its place," was fully proved by the evidence given before the coroner at the inquest held on the bodies of the persons who lost their lives at the great mill fire at Over, in Cheshire, which occurred in October 1874, and which caused a loss of thousands of pounds.

One of the witnesses, William Bullock, spinner, said: "I immediately ran to the bell, and rang an alarm. They used to have buckets at each mule, but they could not find them when the fire was discovered." Another witness, Mr. Haigh, jun., said: "There were two dozen buckets bought some time ago, and each spinner had one at the end of his mule; but they were borrowed by other people, and became anybody's buckets, and on Tuesday none could be found; whether this was owing to the smoke or not he could not say." Mr. Haigh said there were six or eight dozen buckets in the place altogether.

The principal water main should be fixed in the stairway; each main floor should be provided with a hydrant, and a small cock for filling buckets. There should be a lock-up case near each hydrant, containing the following

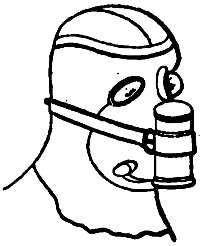
FIG. 114.



articles:—A valve key; a length of Voucher's flax hose sufficiently long to reach the remotest corner of the rooms, and provided and fitted with Tozer's patent swivel union, and a copper hand-pipe; also at least six strong galvanised-iron or leather fire-buckets. As a further precaution, one or two manual pumps should be provided. Printed instructions should be fixed on the wall near the extinction apparatus, containing the following order:—That no person, unless specially ordered, shall remove any portion of the fire-extinction apparatus, except in case of fire; with severe penalties in case of non-compliance with the order.

Fig. 114 shows a model arrangement of fire-extinction apparatus. Fig. 115 represents Dr. Tyndall's respirator, which, if fixed to the mouth of a person as shown, will permit easy respiration for a considerable time amidst the densest smoke. A few of these respirators would not only be exceedingly valuable in case of fire, but might be useful to persons engaged in occupations producing a dangerous amount of dust, such as cleaning cotton-waste, &c.

Fig. 115.



## *Structural Extinction Arrangements.*

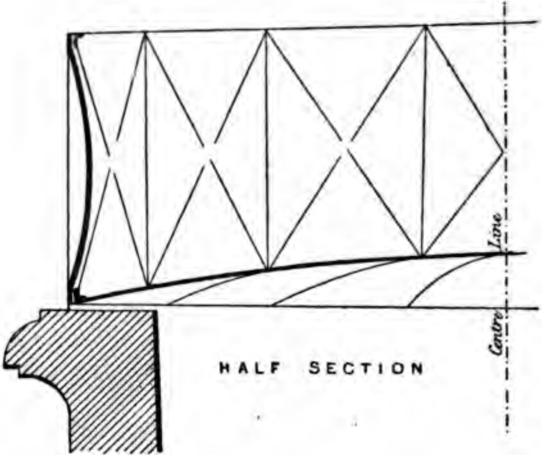
One inventor has proposed wrought-iron hollow girders, in which water would be stored, with the object of extinguishing fires. The idea, however ingenious, is most impracticable, as it would be extremely difficult to keep them water-tight, and corrosive action would ultimately destroy them. Moreover, in case of a fire occurring, the water would evaporate, and if without an elaborate system of safety valves, the steam would most likely explode the girders.

Other inventors propose the circulation of water through hollow walls and floors, thus making the latter shallow tanks, ever ready to discharge their contents on all below; but all such devices have the great disadvantage of being impracticable.

Where mills are connected with mains of low pressure, or where there is no water-supply system, an open-air tank may be provided in the roof, and the water from the gutters led into it. According to Messrs. Shand, Mason & Co., a tank 10 feet long by 6 feet wide by 8 feet deep will contain a supply of water equal to that from the working of a Metropolitan Brigade fire-engine for half an hour—a time and supply sufficient for extinguishing an ordinary fire.

Water tanks may be constructed either of timber, wrought iron, cast iron, or slate slabs. The slate-slab tanks are the most durable. If cast-iron or wrought-iron slabs are used, they should either be galvanised or coated with magnetic oxide by the Barff process. A tell-tale indicator should be provided which will show, in some prominent position, the actual height of the water in the tank. Where possible, it is advisable to have covers to the tanks; they will to a certain extent prevent evapora-

FIG. 116.



tion. An admirable form of water-supply tank is shown in Fig. 116. If the rain falling on the surface of the roof is insufficient to keep the tank well filled, pumps should be provided.

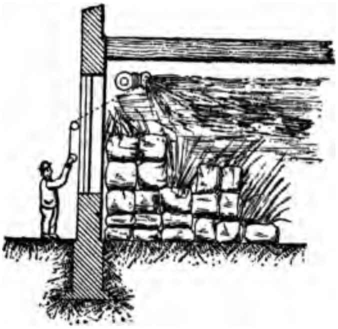
### *Pumps.*

Where factories are unconnected with water mains under pressure, or where the water supply is intermittent, they should have independent pumping machinery. For this purpose Gwynne's centrifugal pump is particularly well adapted. The machine is based on the best principle, and is unsurpassed for economy, efficiency, and simplicity. A pump in a large manufactory will always be found useful, and its existence might, in case of fire, at once decide as to the fate of the building.

### *Extinction by Steam.*

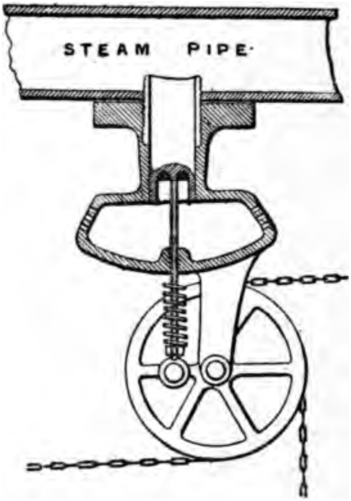
In mills, &c., heated by steam, this system of fire extinction can easily be applied. A special valve has been designed by W. H. Bailey of Salford (see Figs. 117 and 118). One of these valves should be provided for each room. The ropes or chains for working the valves may be connected with the office of the watchman, each chain having attached to it a number corresponding to its room. So that if there is an outbreak of fire at night, by simply pulling the chain corresponding to the room in which the fire exists, the steam can be instantly turned on, and will probably prove effectual (if not in actually extinguishing

FIG. 117.



the fire), in arresting its spread. It will, of course, be understood that the steam itself does not directly extinguish the fire, but by filling the room it excludes the oxygen and thus smothers the flame.

FIG. 118.



The whole range of steam pipes need not constantly be charged with steam, as one stop-valve near the boiler can be used to fill the pipes, and afterwards by pulling the connecting chain and opening the special valve, it can be turned into any room desired.

## *Fire-engines.*

The manufacture of fire-engines has now attained an almost unsurpassable excellence. The continued trials between the two great makers of these machines, Messrs. Merryweather and Shand, Mason & Co., have induced continued improvements, and the steam fire-engines of both these celebrated makers are remarkable examples of applied science.

The simplest form of a fire-engine is what is known as the portable fire-pump, which with hose, swivel-screws, and jet-pipe, costs £2 10*s.* The water may be pumped from any source. A simple and excellent manual pump, the invention of Mr. Tozer, chief of the Manchester Fire Brigade, has been introduced by Messrs. W. H. Bailey & Co. This pump has been successfully used for extinguishing outbreaks of fire. (See Fig. 119.)

FIG. 119.

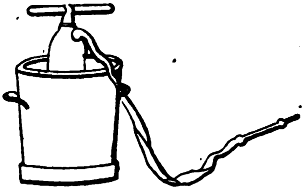
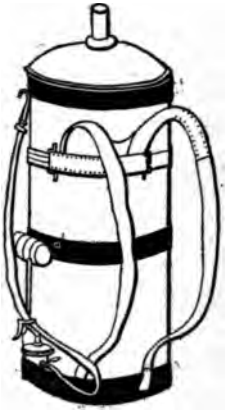


FIG. 120.



The chemical fire-pump known as the Extincteur, is one of the latest, and not the least important addition to the appliances for fire extinction. (See Fig. 120.)

The following is the inventor's description of the apparatus.

The Extincteur or Exterminateur consists of a cylindrical vessel with aperture for charging it with water and chemicals, and with tap and tube for directing the contents into the fire. It is filled with water, after which alkali (in proportion to the size of the vessel) is introduced, which, becoming dissolved, chemicalises the water; a glass bottle containing a powerful acid is then suspended in the water by means of an ingenious arrangement called a cradle, which is screwed into and closes up the aperture at the top of the machine.

The Extincteur is now considered to be charged; in this state it remains until required; but as the acid is still separated from the water in which the alkali has been dissolved, all that is necessary on the outbreak of fire to render the Extincteur efficient, is to strike with an iron hammer, attached to the machine, a brass knob on the top, which being in communication with the glass bottle, breaks it, and instantly the acid, diffusing itself through the water, generates carbonic acid gas at a pressure of from 70 to 100 lbs. per square inch. The water holds the gas in solution, and when the tap at the bottom is turned, the fluid rushes out with great force: immediately on coming in contact with the fire, the carbonic acid gas is liberated, and displacing the oxygen, rapidly extinguishes the fire.

These Extincteurs have been proved to be very effective for the purpose, but as their contents are limited, they should always be supplemented by an ordinary manual pump.

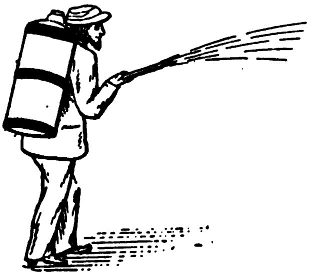
To prevent misconception, it may as well be stated that the gases generated by the chemical agents used are perfectly harmless to health.

One great advantage of the Extincteur is that the discharge of water supersaturated with carbonic acid gas successfully extinguishes burning tar, oils, &c., on which water has often little or no effect. Fig. 121 shows the method of carrying and using the Extincteur.

The Extincteur is also made to act as a manual fire-brigade engine.

Lately, another invention has been introduced, somewhat similar in principle to the Extincteur, e. g. the utilisation of the negative quality of carbonic acid as a non-supporter of combustion. At a pressure of 33 lbs. to the square inch, water will absorb eight times its bulk of carbonic acid, and at 99 lbs. pressure, one gallon of chemicalised water will absorb twenty-four times its own bulk. Therefore, if a jet delivers water impregnated with carbonic acid at a pressure of 100 lbs. to the square inch, and if the delivery from a half-inch jet equals 90 gallons, the carbonic acid which will escape when the water issues from the jet, will be equal to twenty-four times the bulk of the water, or a quantity equivalent to 1960 gallons of water, and this gas will thus exert an immense influence on the fire, by displacing the oxygen necessary to sustain combustion.

FIG. 121.

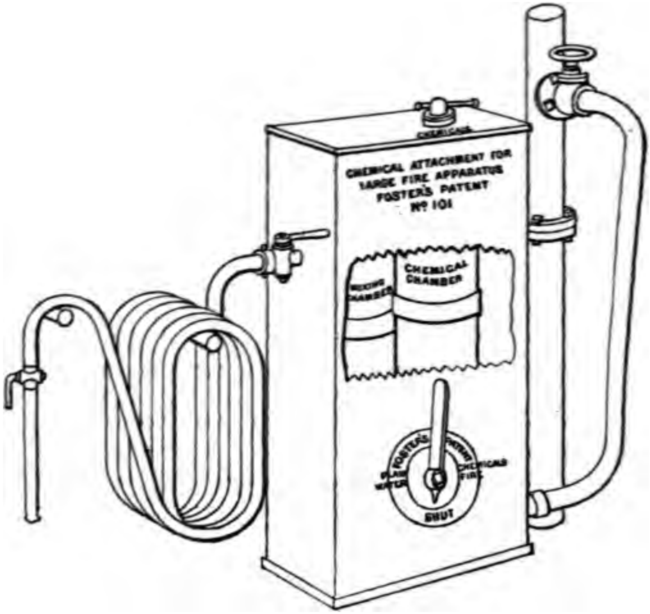


Two forms of extinguishing apparatus are manufactured by the inventors, Messrs. Foster and Greenhill, of Bolton. One, the stationary form known as Foster's Patent Hydro-Carbonic Attachment, is shown in Fig. 122. This form is intended to supply carbonic acid to the water delivered by the ordinary fire-engine, and consists of a chemical container of sufficient capacity to hold quantities of fire-extinguishing chemical agents.

These chemical agents impregnate the water from the fire-engines which is forced through them, and the water so impregnated with carbonic acid issues in one continuous stream on the fire; the water thus saturated with the carbonic acid (or oxygen displacer) extinguishes fire instantaneously.

The second, or moveable form of the invention, is shown in Fig. 123, and consists of a container on wheels, which contains the necessary chemical agents which are constantly under pressure, and which also contains a gauge to indicate the pressure. Both these inventions are based on true philosophical principles, and they are most effectual in their action.

FIG. 122.

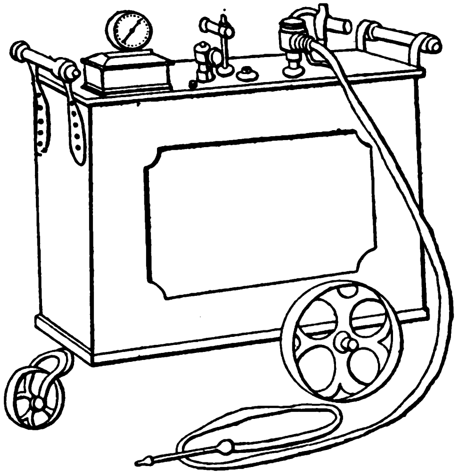


For the larger class of fire-engines, steam or manual, the author begs to refer the reader to the excellent catalogues of Messrs. Shand and Mason and Messrs. Merryweather, all of London; the engines of both these makers are unrivalled.

Without wishing to depreciate the value of large steam engines in particular cases of inaccessibility, the author believes with Mr. Tozer, Superintendent of the Manchester

Fire Brigade, that if the large sums of money that steam fire-engines cost were expended upon smaller appliances it would be much better. Mr. Tozer further expresses himself as follows:—"What was required was in the first place a better construction of buildings, and secondly, the adoption of smaller extinguishing apparatus. When he ordered the steam fire-engine to be used at a fire, he generally looked upon it in the same way as he looked upon the presence of the family physician—It was all 'up.' What was required was to get near to a fire, and grapple with it, not to stand at a distance throwing a jet of water. Money spent upon steam fire-engines would be laid out much more advantageously if used in the purchase of small apparatus, which might be placed at the corner of nearly every street, so that it would be ready for immediate use by police officers and others whenever a fire broke out."

FIG. 123.



Fine sand, dust, or ashes may sometimes be used with effect for suffocating a fire.

For extinguishing small outbreaks of fire a few pounds of carbon disulphide has been tried with success. The combustion of carbon disulphide produces great volumes of carbonic acid gas and sulphuretted acid gas, both of which will instantly suffocate fire.

## CHAPTER XXV.

### FIRE-ESCAPE ARRANGEMENTS.

### *Fixed Appliances.*

For mills and warehouses, the arrangement shown by Fig. 124 should be applied in all cases. It consists of a projecting balcony, arranged for each floor and connected to each other by a ladder. It will be seen on referring to Fig. 125, that the balcony extends to the blank or wall space between the windows, so that the person escaping will not be subject to the flames which may burst through them. Where the wall space between the windows is insufficient in width, the balconies and ladders should be projected 5 or 6 feet from the building (see Fig. 124). These escape apparatus should be fixed on two or three sides of the buildings in the most accessible positions. Lately this arrangement has been pretty extensively applied, but the ladders are commonly placed opposite the windows: in case of fire, descent might be very hazardous. Fig. 125 shows a winding-stair escape arrangement.

Escape openings should always be provided in the roofs as well as ladders for descent. Movement on slated roofs is very difficult and dangerous; special footways should be made from the openings to the side walls. (See Fig. 126.)

Where the roofs are flat, movement of course will be easy and free from danger. Hoist wells may be made a means of escape in case of emergency, but it is most desirable that well-hoist doors should be self-closing; otherwise, in case of fire the hoist wells will act as tremendous air upcasts, and feed the conflagration.

FIG. 124.

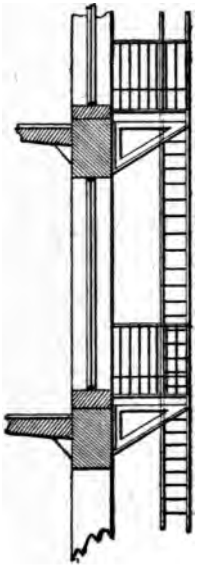
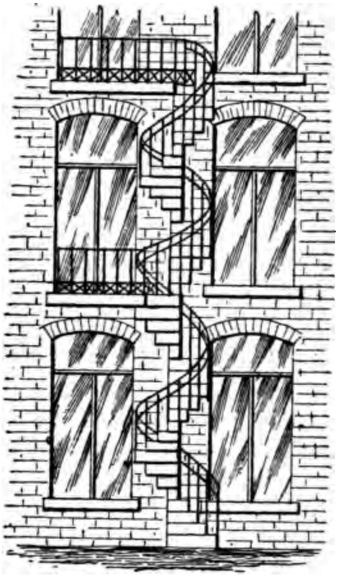


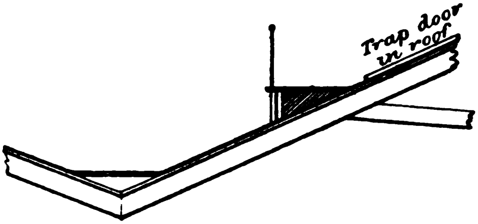
FIG. 125.



The main stairways should be constructed in towers separated from the main buildings and connected therewith by means of balconies.

Where the stairways are in the interior of the building they should be provided with self-closing and fire-resisting doors to each room, and supplementary self-closing doors in the stairways midway between each floor (see Fig. 180, page 264). Should the door leading into the room where the fire is raging be destroyed, the midway door will prevent the stairway from becoming the means of either sustaining or propagating the fire.

Fig. 126.



*Portable Appliances.*

All mills and warehouses, &c., of magnitude should be provided with portable fire-escape ladders. Since these excellent contrivances were first introduced, they have been considerably improved. Fire-escape appliances in which the shoot is formed of combustible material should never be used, as they may prove disastrous. Some time back a fire occurred in Birmingham by which a lady, her child and sister, were destroyed in descending a fire-escape, owing to the rapid destruction of the inflammable material forming the shoot.

Fig. 127 shows a modern fire-escape known as the London Model. It consists of one main ladder on wheels, behind which a strong copper-wire netting is fixed, lined with strong canvas which has been prepared to resist fire, and which persons may descend with perfect safety and comfort. A second ladder is attached near the summit of the main ladder and fixed by levers; this ladder will reach another storey; sometimes a third additional ladder is attached to the second one.

Lately a novel escape ladder has been introduced by a Mr. Brown, of Dublin, and is known as Clayton's telescopic fire-escape. This arrangement consists of three ladders

FIG. 127.

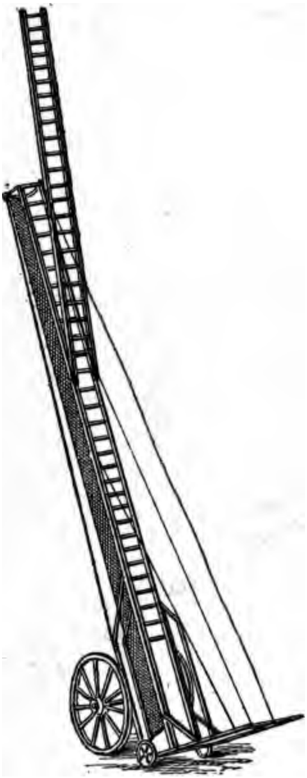
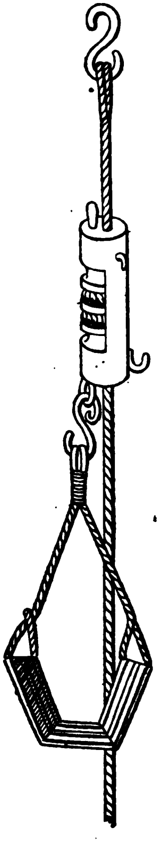


FIG. 128.



constructed on the telescopic principle: the ladders are of double the ordinary width so as to allow firemen to pass each other in ascent or descent. The sides are strengthened by galvanised iron lattice-work which acts as a protection. The lower ladder rests on a strong frame, with a portion hinged to fold out, to give leverage and ensure perfect control over the machine. The wheels on which the escape moves, are attached to the ladder by means of carriage springs; the axletree of the wheels forms a windlass by which the ladders are moved by galvanised steel-wire ropes; by an ingenious arrangement the ladders can be erected to any desired height. The weight of the machine is about 14 cwt., and can be raised to the height of 60 feet by moderately strong men. For the purpose of suppression of fire, the machine offers advantages over others, although it is questionable whether it would be found as effectual and quick in the work of rescue as the model fire-proof shoot.

Very simple, portable, and inexpensive fire-escape appliances have lately been invented; among them is the appliance introduced by Mr. Sinclair, of London, known as the Spiral Descender (see Fig. 128). It consists of a strong iron cylinder with four spiral grooves turned upon its surface, and partly enclosed in a sheath of the same metal; the length of the cylinder is 5½ inches long by 1¾ inches in diameter.

The descending rope passes round two or more of the grooves which regulate the speed of the descent; a strong galvanised iron hook is firmly attached to any fixed support of the building; a sling or girth is fastened to the rope for attaching to the person wishing to descend; the girth is passed under the arms, the hook is passed through the girth and attached to the end of the Descender; this will necessitate an upright position and prevent the danger of giddiness; should the girth not be handy, it will be sufficient to use any rope, strap, shawl, &c. The rope is 60 feet long, and chemically prepared to resist fire. The cost of this appliance is trifling, and for small workshops a number of them may prove of incalculable value.

Fig. 129.

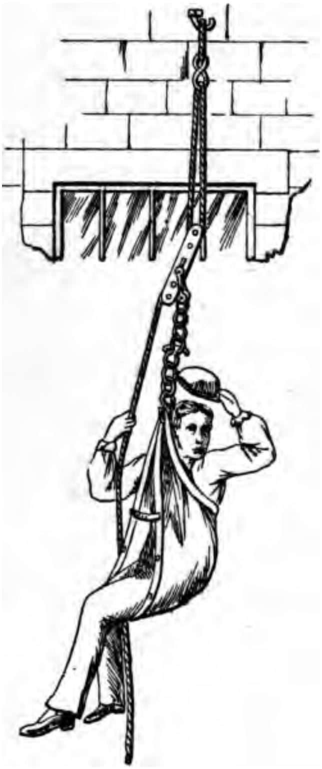
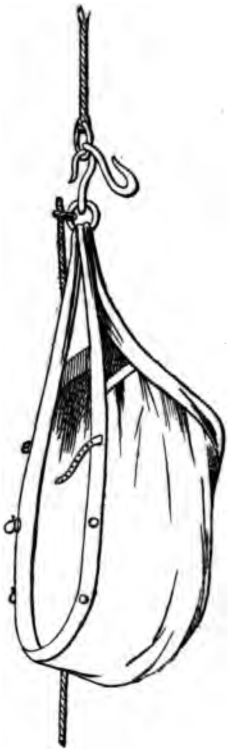


Fig. 130.



Wethered's appliance (see Figs. 129 and 130) consists of a small frictional pulley-block with four fixed sheaves, having a central moveable sheave riveted through slots in the cheeks of the block to a shackle, with a short chain and ring attached for the purpose of suspending the block or weight to be lowered, so that when a person is suspended, the weight causes the moveable sheave to close on the nearest fixed sheave, nipping the rope and sustaining the principal portion of the weight.

To lower others the block is hung up by the ring of the chain to the wall hook, the person wishing to be lowered being placed in the bag, which should be rendered incombustible and attached by the short end of the rope to the hook; the descent is controlled as with an ordinary block, each end of the rope being used alternately until all are saved.

To lower oneself the shortest end of the rope is hung up to the wall hook, and the person descending is attached by the bag or belt to the ring of the block as at Fig. 129, holding the rope as shown, the descent being controlled in the ordinary way by the other rope: the block sustains the greater part of the weight and reduces the friction on the hands to a minimum. When a wall hook has not been fitted, the apparatus may be securely suspended by throwing one end of the rope round some fixed article in the room or to the sashes of the window; but it is advisable to fix firmly a galvanised hook over each window. The cost of this apparatus varies from 20*s*. to 35*s*.

The rope should be made fire-resisting by one of the methods described in the work.

## CHAPTER XXVI.

### PRECAUTIONS TO BE TAKEN IN CASE OF AN OUTBREAK OF FIRE.

PRESENCE of mind should not be lost on the intimation of fire; much depends on the coolness of the discoverer. If he is panic-stricken, the disaster will be exaggerated. Immediately the fire is discovered, he should give information to the first fire-brigade station, either by telegraphic-telephonic communication or steam-whistle; and, if these do not exist, he must adopt the readiest methods available.

After clear intimation is given to the fire-brigade station and to the police, obtain what ropes, ladders, blankets, and buckets are available.

If any people are in the burning buildings, two or more persons carrying ropes may be able to ascend to the roofs, either by the adjoining premises, or, if these do not exist, by ladders, at some part of the building where the fire has not reached. Ropes could be fastened to some projection and passed to the persons in danger, who could thus lower themselves into the street. In the meantime, presuming no fire-escape has arrived, all the available bedding, blankets, carpets, &c., should be gathered together.

The spectators can, by a little intelligent supervision, be instructed to do much towards saving the inmates of the burning structure.

It is advisable that bystanders should acknowledge some leader, as this will save some confusion and time.

The impromptu brigade must now—if there are no other means handy—hold, stretched out in mid-air, the carpets or blankets to receive the inmates who throw themselves from the windows.

Not until all the persons are freed from their fiery bondage should attempts be made to arrest the devouring element.

All doors and windows accessible and known to be open, should be instantly closed; and if sand, mud, or earth is handy, all the crevices should be stopped up. Persons at a fire have a habit of breaking the windows and doors of the burning structure. This practice cannot be too severely condemned; every broken window offers free passage to the air or oxygen which rushes into the building to support and increase combustion, which could not exist if the source of the necessary element of combustion was cut off. In the absence of a fire-engine or hydrants, and if there is a source of water in the neighbourhood, the impromptu firemen should place themselves at arm's length in a continuous line, reaching from the site of the conflagration to the source of the water supply, and pass buckets of water one to another carefully to the flaming building: by this method a constant supply of water can be kept up.

Instances have been known of fires having been smothered by throwing ashes or sand upon them. This practice might be tried if the materials are handy.

### *Precautions for Inmates.*

In all factories and workshops it is important that all the workpeople should know the easiest means of escape; many lives have been lost from ignorance of accessible outlets.

In case of fire, the foreman should, by a calm bearing and language, stimulate courage and prevent panic. However small the fire may be, the foreman should remain in the building until all the operatives have escaped.

When all means of escape are cut off, sheets, blankets, &c., should be gathered for use, and on the approach of the fire, the inmates should roll themselves in the blankets or sheets. As the products of combustion are lighter than the air, they ascend to the ceiling; consequently, near the surface of the floor will be comparatively free from smoke. Therefore, to prevent suffocation, the inmates should lay themselves on the floor; and, if they wish to move, they may do so on their hands and knees. A worsted stocking, handkerchief, or flannel slightly moistened, drawn over the face, will filtrate the smoke from the breathing-air, and breathing is also comparatively easy.

If there are no especial fire-escape arrangements, the inmates should gradually press towards one window or door outlet, and not on any account to several, as the opened window or doors are only so many oxygen inlets to feed the flames. Windows should not be broken for similar reasons.

If there are no fire-escapes, probably blankets outstretched by the crowd may be ready to receive the inmates.

They should throw themselves down one after another. The precipitate fall of two or three at the same time will only result in shattered limbs.

If outstretched blankets are not presented, the last resource, if ropes are handy, is to tie them to some firm object, and let them hang to the ground for descension; if ropes are not handy, sheets may be twisted and joined to form ropes.

If any of the unfortunate inmates are burned, medical aid should of course be instantly summoned; in the meantime the sufferer should be taken under cover and, if possible, put to bed. All remnants of clothing should be removed from the sufferer with the greatest care, so as to avoid removing the skin or breaking a blister. It is common to lance blisters, but this practice only intensifies the suffering.

For covering the injured parts, wadding, clean wool or cotton are the most suitable; they should be put on the injured parts tenderly and completely, so as to exclude the cold air. For alleviating the pain of the most distressing nature, whiting, applied wet and continuously moistened, or linen rags, soaked in a mixture of equal parts of lime-water and linseed oil, will be found useful.

If a person is in a state of coma from the effect of smoke, cold water and hot water alternately should be thrown on his face; if this fails, he should be turned with his face downwards and his arms placed under his forehead. Pressure should then be applied gradually under the ribs, the body being turned from side to face alternately. This process should be continued about 18 times a minute, and sufficiently long to reproduce respiratory action.

When, in about two days after the accident, the blisters assume a white, milky, and inflamed appearance, the water should then be let out. The operation of lancing the blister should be left to a skilled surgeon, who will possibly be able to ascertain the permanent effect the accident will have on the sufferer and act thereby. For dressing burns, however, a good and simple remedy is to spread on them lint, covered with a mixture of wax and oil.

Masters would do well to arrange amongst their workmen local fire-brigades, obtaining the services of a competent fireman to give them instructions.

Hundreds of destructive fires might never have occurred had such local fire-brigades existed. At present, if a fire breaks out in factories, the workpeople are panic-stricken, and all is chaos and confusion.

## CHAPTER XXVII.

### STRUCTURAL FIRE-RESISTING ARRANGEMENTS.

We have no evidence that the antique nations, prior to the Romans, made any attempt to construct their buildings so as to resist fire; on the contrary, from the evidence of the great conflagrations which occurred, we may fairly assume that no attempt in that direction was made.

The Romans, in the construction of the roofs of their earlier temples and basilicas, used timber for the framing; the basilicas were consequently often destroyed at the celebration of the High Mass when the high altars were ablaze with lighted candles.

The conflagrations originating at these holy festivities occurring often, no doubt led to the adoption of masonry for constructing the roofs, as we find the Romans at a later period constructing their basilicas entirely of stone, the roofs being formed with round arch-vaultings.

When Rome was at the height of its glory, the municipal arrangements for promoting and maintaining the health and safety of the people almost approached perfection; every Roman citizen was bound to have a machine for extinguishing fire of a size proportionate to his household.

Immediately after the fall of the Roman empire, and after the evacuation of ancient Gaul by the Roman legions, the southern portion of that country was overrun by barbaric Teutons. Finding themselves surrounded by the abandoned art creations of the Romans, the Teuton savages gradually became more civilised, their increasing intelligence being naturally attended with a desire to imitate their predecessors.

In the construction of their temples they imitated the forsaken basilicas; but owing, no doubt, to their ignorance of the art of vault-construction and the dangers from fire, they covered their temples with roofs of timber.

Gradually learning the error of this inflammable method of construction by costly experience, and becoming more and more enlightened, we find them successfully copying the arched vaultings of masonry left by their predecessors; the spandrils of the upper surfaces of the arches they filled up with masonry to the stone of the roof, and finished off with roof-tiles.

The early Gallic low-pitched roofs were superseded by roofs of a higher pitch. The Romans had adopted the pitch for the roofs commonly used at their own imperial city, but the Teutons in southern Gaul found these low-pitched roofs little suited for their adopted country with its great rainfall, however suitable they might have been for the sunny Italian cities.

The Teutons, therefore, used higher pitched roofs; this form of roof naturally led to the adoption of a pointed arch as being more in harmony with the altered and higher roof-pitch. The character of the door and window-arches underwent similar changes, the round arches being replaced by pointed ones. We thus see that the desire to make the buildings fire-resisting had the effect of producing a distinct style of architecture; the rude pointed arch of the early Gallic builder was the germ from which was developed the splendid vaultings of the Middle Ages. For habitations and workshops, however, timber was used for the floors and roofs. We have lamentable proof of this by the great fire of London in 1666: by this conflagration streets and buildings of all descriptions were destroyed. Italian builders of the same period were, however, wiser in this respect, for they constructed their spacious ceilings, partitions, and floors of brick in such a way that the arches of the ceilings were scarcely thicker, in proportion to their span, than is a tolerably thick egg-shell to the dimensions of the egg.

This method of construction applied to domestic and industrial buildings may explain the comparative immunity of the Italian cities from destructive fires. In England the Nottinghamshire builders have, for upwards of three centuries, employed an ingenious system of flooring which, from the materials used, is practically fire-resisting. The essential feature of this system consisted in the employment of plaster of paris (gypsum or sulphate of lime).

This substance, which was procured from Derbyshire, was used for the floors, the *modus operandi* being as follows. The coarse material is calcined, and then ground and kept perfectly dry until required; when it is to be applied, it is mixed with water to the consistency of mortar, then laid over the wooden joists, reeds, or laths, and spread to a uniform thickness of 10 inches; it rapidly hardens, and on the third day is smoothed down with a trowel. Thanks to this system of floor construction, Nottinghamshire has had a remarkable immunity from conflagrations.

The Corporation of London in the last century, becoming more fully alive to the dangers of inflammable buildings, were ready to welcome any attempt to impress upon builders the importance of erecting buildings that would effectually withstand fire. In 1776 they erected an obelisk on Putney Heath, to commemorate the satisfaction felt by the committee at the results of certain experiments made in the same year, and which are described in a pamphlet by David Hartley, M.P. for Hull, entitled "A Description of the Invention and Use of Fire-plates for the Security of Buildings Against Fire." A reprint by Mr. Hartley's nephew in 1834, states that buildings may be constructed so as to resist any amount of exposure to fire, by fixing the fireplates above and below the timbers, and filling in the space between with rubbish and dry sand. Repeated trials of this plan were made with very successful results, the timbers being merely charred to the depth of an inch or so of their substance. Hartley also suggested the employment of tinned-iron and rolled copper plates.

In 1774 the inventor, David Hartley, was voted 2500*l.* by the House of Commons, and the same year an extension of his patent was granted to a period of 31 years; but the invention was only applied in a very few instances.

The following are the special qualities required in the materials constituting a structure to make it perfectly fire-resisting:—

First. Incombustibility.

Secondly. Capability of resisting a temperature of at least 2000° Fahr. without disintegration and with a minimum coefficient of expansion or contraction.

Thirdly. The materials must be bad conductors of heat.

It will be interesting to compare the principal building materials to ascertain their relative positions as regards the special qualities just enumerated.

First. (Note. Those materials which are combustible are almost invariably bad conductors of heat, and have a low coefficient of expansion and contraction).

The first class includes all kinds of timbers.

Secondly. Those materials which are incombustible, good conductors of heat, and have a low coefficient of expansion and contraction.

The second class includes metals, iron, steel, &c.

Thirdly. Those materials which are incombustible and are either good or bad conductors of heat and have a low or high coefficient of expansion or contraction, according to their density and chemical constituents.

The third class includes the minerals, &c., used in construction, such as stones, bricks, cement.

Timbers. The closer fibred or denser the timber, the better (oak is the best) for resisting fire.

It is not generally known that a wooden beam will withstand a powerful dead heat upon its sides for an indefinite period without igniting, unless a transverse section of the fibre, such as a knot (where a branch has been severed), presents itself to the action of the fire.

Thus it is at the ends that a piece of wood exposed to powerful heat most readily ignites.

The gases formed in the substance of the timber by the action of heat applied to its surface, expanding as they are evolved, are disengaged from the ends of the fibres.

That is, if the ends of the timber are exposed to the action of the fire, these gases, being highly inflammable, rapidly ignite the substance of the wood. It is, therefore, important, in adopting systems where timber is used, not to allow any cross-section of the timber to be exposed.

### *Iron.*

The following are the results of a series of investigations carried out by the late Sir William Fairbairn, F.R.S., owing to the failure of several buildings supposed to be fireproof.

The results of the investigations formed the basis of a report presented to the British Association for the Advancement of Science in 1856.

REPORT ON THE TENSILE STRENGTH OF WROUGHT-IRON AT VARIOUS TEMPERATURES.

| No. of Experiment. | Temp. Fahr. | Breaking Weight in lbs. | Breaking Weight per Square In. in lbs. | Breaking Weight per Square In. in tons. | Mean Breaking Weight per Square In. in lbs. | Direction of Strain in Regard to Fibre. |
|---|---|---|---|---|---|---|
| 1 | 0 | 32·660 | 49·000 | 21·879 | 49·009 | along fibre |
| 3 | 60 | 27·780 | 43·406 | 19·377 | .. | across „ * |
| 12 | 340 | 31·980 | 49·968 | 22·307 | 46·018 | along „ † |
| 13 | 340 | 28·620 | 42·088 | 18·789 | | across „ |
| 15 | scarcely red | 23·520 | 38·032 | 16·978 | 34·272 | across „ |
| 16 | dull red | 18·540 | 30·513 | 13·621 | | across „ |

* Small steely spots in fracture. † Too high.

**Table of Elongation Produced by Increase of Heat.**

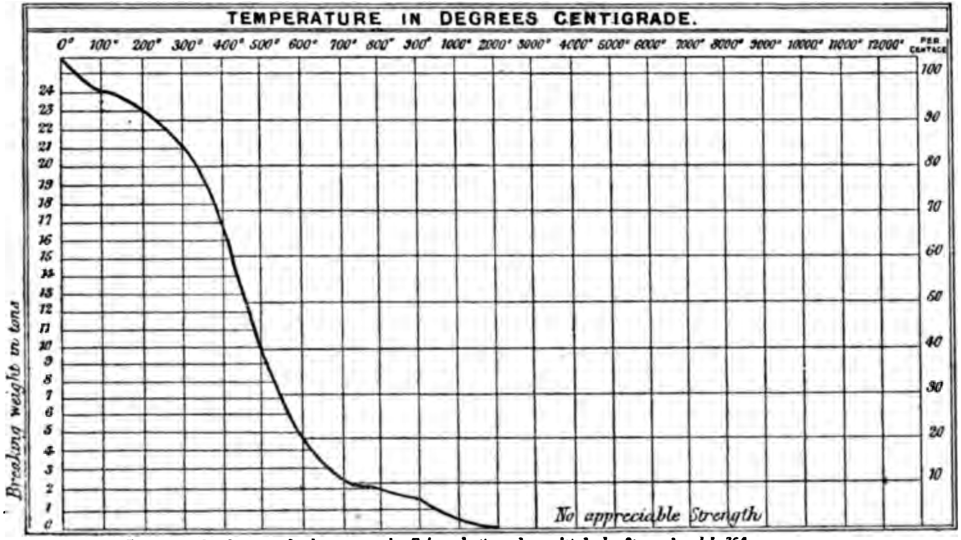
| Temp. Fahr. | Elongation per ton per inch. | Mean Elongation per unit of length and weight. |
|---|---|---|
| 30° | 0·00284 | 0·00284 |
| 60° | 0·00297 | 0·00247 |
| 60° | 0·00197 | |
| 114° | 0·00177 | 0·00177 |
| 212° | 0·00173 | 0·00162 |
| 212° | 0·00142 | |
| 212° | 0·00182 | 0·00178 |
| 250° | 0·00164 | |
| 270° | 0·00192 | |
| 310° | 0·00175 | 0·00164 |
| 325° | 0·00153 | |
| 415° | 0·00175 | 0·00183 |
| 435° | 0·00192 | |
| Red heat | 0·00341 | 0·00340 |

Shows that the elongation per unit of length and weight is nearly the same at all ordinary temperatures, but is more than doubled at red heat.

The results of Sir William Fairbairn's experiments appear to be corroborated, and are supplemented by a very interesting series of experiments carried out by Dr. J. Kollmann on the strength of iron and steel at high temperatures, and communicated by him to the 'Verhandelungen des Vereins zur Beförderung Gewerbfleisses.' A table is given by Dr. Kollmann containing the results of fifty-two experiments showing the effects of rise of temperature in the reduction of the resistance of iron to rupture, and the increase in the contraction of sectional area as well as of elongation.

From this table we find that taking the initial temperature at 0° Cent. (32° Fahr.), and the resistance of iron to rupture at this temperature at 23·81 tons per square inch, and calling this breaking load 100, then at a temperature of 200° Cent. the breaking load is decreased to 22·6 tons, or 95 per cent. of the original strength at the

**DIAGRAM SHEWING THE REMARKABLE EFFECT OF HEAT ON THE STRENGTH OF IRON DEDUCED FROM RESULTS OF D^R KOLLMANN'S EXPERIMENTS.**



*To reduce the Centigrade degrees to the Fahrenheit scale multiply by 9/5 and add 35°*

normal temperature; at 300° Cent. to 21·4 tons or 90 per cent.; at 400° to 17·39 tons or 73 per cent.; at 500° to 9·14 tons or 38 per cent.; at 600° to 4·44 tons or 19 per cent.; at 700° to 3·94 tons or 16 per cent.; at 800 to 2·54 tons or 11 per cent.; at 1000° to 0·05 tons or 4 per cent.; while at 2250° it broke, without the application of any appreciable load.

### *Minerals.*

Stones. From the chemical constituents of sandstone it is an excellent fire-resister; it is almost entirely composed of silica, a constituent which requires intense heat to produce its fusion.

Among the limestones the dolomite is the worst as it becomes calcined and disintegrated at a comparatively low temperature.

The primitive or igneous rocks also soon become disintegrated on exposure to heat.

Limestone entered largely into the construction of the cities of Chicago and Boston, before the terrible conflagrations which almost destroyed them; during the fires the limestone proved to be a disastrous failure, treacherous, crumbling and falling to pieces when exposed to a comparatively low temperature.

### *Artificial Stones.*

Owing to their composition, which consists chiefly of alumina and silicate of lime, artificial stones will successfully withstand the most intense temperatures.

Fireclay or terracotta, owing to its silicious constituents, also resists the most intense temperatures.

In choosing terracotta for fire-resisting purposes, the constituent percentage of silica should be ascertained: it should not be less than 60 per cent. Ordinary Portland cement loses its adhesive qualities when exposed to a high temperature.

Lime concrete disintegrates on exposure to a moderate heat.

We shall now consider the building materials enumerated as to the important qualities of resistance without fracture or disintegration when subject to successive changes of temperature, such as for instance the effect of a jet of cold water upon a heated iron beam.

In the first class, which comprises all kinds of timber, the quality of resistance to excessive changes of temperature exists in a high degree.

In the second class, which includes all metals, cast-iron is very inferior. If a jet of cold water is suddenly brought into contact with a highly heated cast-iron beam the granular molecules of iron will instantly separate, and fly in all directions. After the fire in Hadley's Flour Mills in Thames Street, London, it was discovered that the great portion of the cast-iron girders that had fallen, were shorn off close in the bearing, due to the inequality of the temperature of the wall, and the temperature of the fire. Malleable and wrought iron would, under similar circumstances, be liable to distortion.

In the third class, stone, bricks, terracotta, plaster concretes and cement present a considerable diversity in their behaviour under great changes of temperature. The action of cold water thrown on a stone highly heated, is similar to that upon cast iron under the same conditions.

Cements are not so much affected.

Experiments have been made with blocks of fireclay or terracotta, by placing them in the furnace of a Cornish boiler for two hours, and when white-hot they were taken out and plunged into cold water: the result was a few slight fractures, but not such as to substantially weaken the blocks. Experiments have also been made with samples of Dennett's concrete; these were heated in the furnace of a Cornish boiler for fifteen minutes, and then plunged into cold water; the concrete crumbled at a comparatively slight pressure. The following account of a fire, however, is a sufficient proof of the value of concrete as a fire-resisting material:—"Shortly after ten o'clock yesterday morning, a fire broke out in the works used by the Boulinikon Floorcloth and Manufacturing Company Limited, Worsley Street, New Bailey Street; the fire resulted from the boiling-over of a quantity of oil contained in a vat in the colour-grinding room on the ground floor. The Salford, Broughton, and Pendleton Fire Brigades extinguished the fire in about three-quarters of an hour, and as the room in question is fireproof, the flames never spread beyond it, and the loss is under 100*l.*" —*Examiner and Times*, April 2nd, 1873. The fire, which was exceedingly intense, took place immediately under and within three feet of the concrete arches forming the floor. The brick and stone work some distance from the fire had to be replaced. The concrete did not exhibit the slightest traces of injury.

Mr. T. E. Knightley, who has made a series of experiments upon the fire-resisting qualities of concrete made with Gibbs' slow-setting cement, lays particular stress on the latter ingredient, containing as it does a minimum percentage of lime, that substance having an important bearing upon the fire-resisting quality of concrete. Deductions from Mr. Knightley's experiments show that concrete made of one part of Gibbs' slow-setting cement, three parts of crushed pottery, and three parts of burnt ballast can resist excessive changes of temperature. An elaborate series of experiments were made by Mr. Hyatt with Portland cement concrete of special constituents, which go to show that concrete can be made that will resist exceedingly high temperatures; see article on Concrete, page 254.

The following extract—deductions drawn from observations of the effects of the fires in Paris during the Commune—is especially valuable.*

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* Vide 'Bulletin de la Société Centrale des Architectes,' 1871.

1. Walls of freestone.—The walls constructed of freestone are seriously deteriorated, the stone being destroyed by disintegration and the calcination of the limestone.

2. Walls of rough stone.—Rubble walls covered with a thick layer of plaster have, owing to this preservative coating, remained unchanged, and generally they will be retained in the process of reconstruction.

3. Brick and millstone-grit walls.—Walling of these kinds has generally resisted better in cellars and underground construction; and as to the brick in partition walls, the brick flues of chimneys remained almost intact.

4. Floors, roofs, and timber partitions.—Wood in floors and roofs has been completely consumed; but in wooden partitions, where a coat of plaster sufficiently thick was exposed to the action of fire, the wood has been completely preserved. Some curious facts have been the result.

A plastered angle post having been attacked in an upper storey, the fire afterwards extended itself into the interior of the post without affecting its external surface.

Oak lintels covered with plaster have resisted, without injury, the flames which traversed the bay of which the lintels formed the upper part.

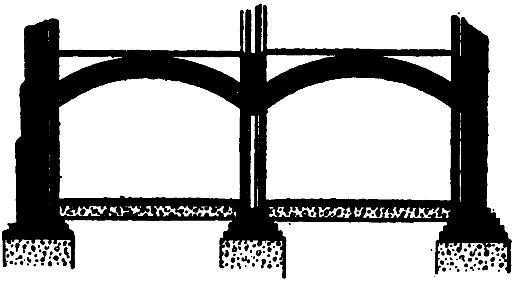
5. Floors and roofs of iron.—Iron has not resisted the action of fire. If it has not been consumed like wood, it has undergone twisting and contortion, which rendered it useless for future use. The utter failure of unprotected iron in resisting fire was clearly seen at the ruins of the Palais de Justice, the Hotel de Ville, and the Théâtre Lyrique; the iron was bent into innumerable fantastic shapes.

For the purposes of comparison, we will arrange the various systems of fireproofing according to their constituents of construction.

1st. Floors formed of ground vaultings of masonry or brick, supported on piers of the same material.

If the arches of this system be of a minimum thickness of 9 inches, it is a most perfect system, and is admirably adapted for basement floors; but for upper floors it is, for ordinary purposes, inapplicable, in consequence of the enormous weight and the large space required for the piers and floors, and also on account of the great lateral pressure exerted by the arches on the external walls, necessitating the use of buttresses and of enormously thick walls. (See Fig. 131.)

FIG. 131.



2nd. Floors formed by a combination of cast-iron girders and brick arches.

This system originated soon after the great invention of cotton-spinning by machinery, and was a commendable effort in the direction of constructing buildings capable of resisting fire. The system, however, had great defects, as will be seen by the following account of a fire which occurred in 1827, at a mill in Leeds constructed on this system.

It appears that the upper floor, which was filled with flax, was the first to become ignited.

The roof next fell in; and the intense heat of the fire so affected the iron girders supporting the floor as to cause them to collapse, falling upon and destroying the floors below.

This failure on the part of the iron columns led the late Sir William Fairbairn to institute a series of experiments on the effect of heat upon the strength of iron.

Two buildings belonging to Mr. Cubitt, were filled with joinery; one was constructed with iron girders and brick arch floors; the other, with ordinary timber flooring. A fire occurred: the fireproof building utterly collapsed, the other remained with the roof on.

Alderman Humphrey, of London, built his mill on the iron girder and brick arch system. A fire occurred: the system proved an utter failure, and the mill was burnt down.

The Tooley Street warehouses were constructed with iron girders and brick arches supported by iron columns. At the great Tooley Street fire they proved quite inadequate to resist the progress of the conflagration.

The unprotected iron columns becoming heated, eventually collapsed, and the whole of the iron girders and brick arches fell down with a crash.

From the manner in which they fell, they tended to the more complete and rapid combustion of the articles in the warehouse, than would have occurred had the floors been of timber.

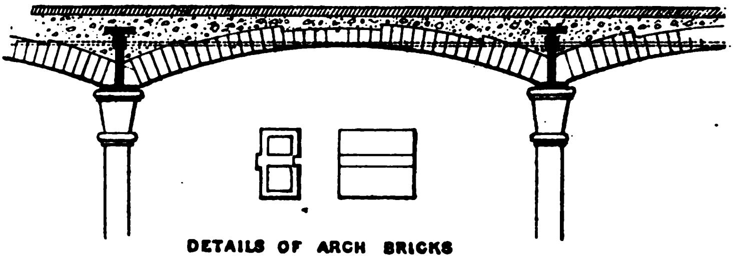
As originally constructed, the arches were made to depend upon each other for resistance to lateral pressure. This method of construction, independently of the action of fire and water, is very dangerous, as the failure of one of the girders or arches from any cause would necessarily involve the collapse of the whole structure.

The following failure (an account of which was published in 1845 by Sir Henry de la Beche, and in a paper entitled "A Report on the Fall of a Cotton Mill and of a prison at Northbeach") is attributable to the defect of making the arches dependent on one another.

The accident occurred while one of the arches, which was found to have settled, was being replaced, and it commenced by the failure of one of the cast-iron bearers in the upper floor, in consequence of the lateral thrust of an adjoining arch. The giving way of the beams was immediately followed by the successive failures of the beams adjoining it, and the falling in of the arches which these beams supported. This occurring on the upper floor, all the other floors immediately gave way beneath the accumulated weight of those above. The crash, it appears, was almost instantaneous: the whole building, which consisted of five storeys, giving way at the same time, causing the death of twenty persons. By this failure, the necessity of making each arch practically independent of the others, was too palpable to be ignored, and wrought-iron tie rods were henceforth generally used to take the lateral strain.

Fig. 132 is a section of the floors of the Saltaire Mills, Yorkshire, designed by the late Sir W. Fairbairn. The girders are tied together by means of tension rods. The spandrils of the arches, which are built of hollow bricks, are filled up level with cement concrete, and the whole covered with wood boards.

FIG. 132.



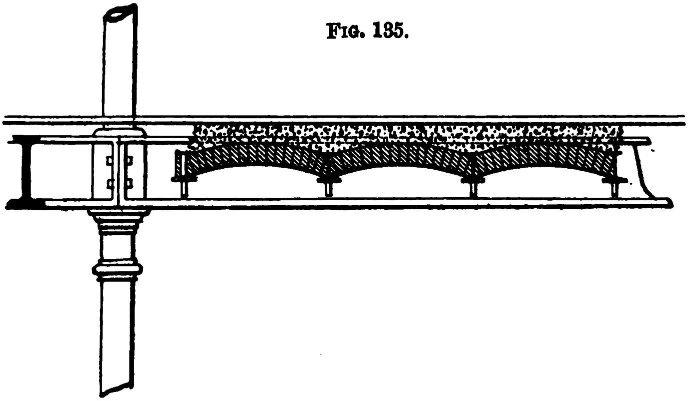
DETAILS OF ARCH BRICKS

FIG. 133. FIG. 134.

Figs. 133 and 134 show details of hollow bricks used for the arches.

Fig. 135 represents a section of a system of flooring that is generally adopted for mills and warehouses in Lancashire. The main girders are of cast iron, the cross girders of wrought iron. These wrought-iron cross girders are supported on seats cast on the main girder, and to which they are tied by wrought-iron angle pieces.

FIG. 135.



The arches are turned on the rolled girders, and are usually 4½ inches thick. The spandrils are filled up level with concrete or cement, and boarded over.

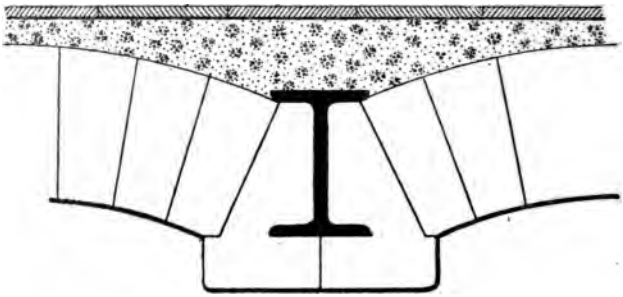
As there is no protection for the main girders from becoming heated in case of the outbreak of fire, this system is defective.

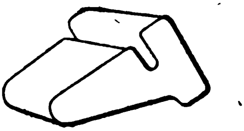
The floors of the Grosvenor Hotel and the London and Brighton Railway Station, Pimlico, are constructed on Mr. Bennet's system. This inventor employs a special form of hollow bricks, joggled at the sides, so that when laid and tied by means of wrought-iron rods which are encased in the brick cavities they lock together, each brick being in contact with and supported by six adjoining bricks. This system of arching has the advantage of lightness, and the tie rods are practically safe from the effects of heat.

Mr. Bennet constructed an experimental arch on his system with a span of 15 feet and a rise of 2 feet 3 inches, loaded to 267 lbs. to the square foot. This arch was found to be quite elastic, the deflection being about $\frac{9}{16}$ of an inch; the fixing medium consisted of Portland cement and sand.

The absolute necessity of protecting iron girders from intimate contact with fire, was not practically appreciated up to the year 1873, when Mr. Whichcord devised a fire-brick and clay casing for enclosing the iron girders. (Fig. 136.)

FIG. 136.





DETAIL OF GIRDER ENCASEMENT

In the construction of the National Safe Deposit Company's building, this system of girder protection was employed.

The lower flanges and webs of the girders are encased with fireclay blocks about 9 inches long, and a minimum thickness of 1½ to 2 inches, and so shaped as to form a skewback for the reception of the arched bricks, and concreted slabs, joists, &c. The blocks are made sufficiently large to allow for expansion. The fixing medium is cement.

An experiment was made to test the efficacy of this system. A furnace 4 feet wide and 15 feet long was constructed, and a rolled joist 15 feet by 10 inches deep, 5 inches wide, weighing 7 cwt., and covered with firebricks, was laid in the furnace longitudinally, so as to span the furnace lengthways; arches were turned from the girder to the side walls, and the whole covered with concrete to represent, as nearly as possible, an actual floor at a span of 15 feet; the uniformly distributed breaking load of the girder was 26 tons; it was loaded by means of pig iron to 6½ tons, after drying the structure with a slow fire for a few days.

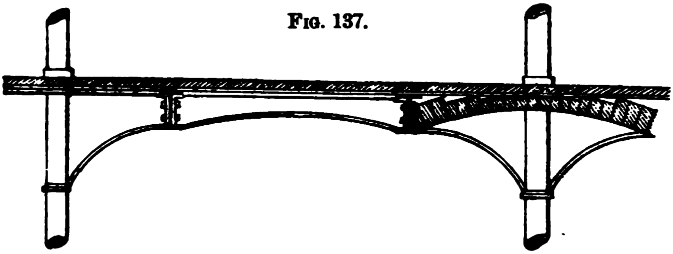
The first experiment was made by keeping up a fierce fire for two hours and a half and then suddenly deluging the hot bricks with water. As the girder became heated the deflection gradually increased to 1¼ inches; but when cold and relieved of its load it completely regained its normal state. Apparently the fire had no effect whatever on it, although the bricks of the furnace and the blocks protecting the iron were vitrified on the surface.

A second experiment was tried, the furnace having been rebuilt. A fire of dry wood was lighted and kept up as fiercely as possible for one hour and a half, and then moderately for twenty-seven hours, after which it was quenched by a jet of water from a hose.

The deflection of the girder, which was $\frac{3}{32}$ of an inch when cold, increased to 1 inch at the fourth hour, reached a maximum of $1\frac{3}{16}$ inch in eight hours, and remained at about 1 inch until the fire was put out. After the extinction of the fire, and when the load was removed, the still heated girder showed $\frac{3}{8}$ of an inch deflection. The fireclay blocks were uninjured, and the girder perfect in shape and surface; when cold the deflection was $\frac{3}{32}$ of an inch, as before the experiment.

Scott's system is shown in Fig. 137.

FIG. 137.



The columns or supports have cast, or otherwise affixed to them, brackets generally measuring in length half the width of the bays, or about 5 feet; therefore the brackets will project (if the bays are 10 feet wide) 2 feet 6 inches each way from the centre of the columns. To the ends of these brackets, rolled girders are bolted which carry the arching or other material forming the floors, and the ends of the brackets are connected together by means of cast-iron or arch beams, and the bolts which fix the rolled joists to the end of the brackets, also connect them to the end flanges of cast-iron arch beams.

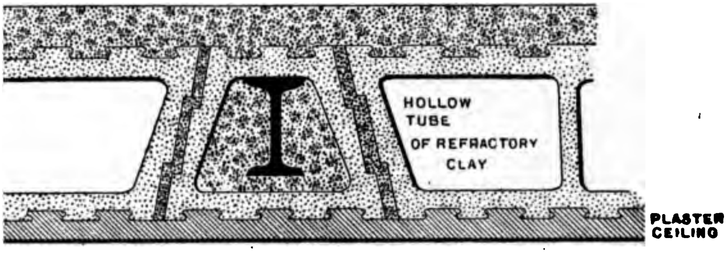
The rolled floor girders are about 5 feet from centre to centre, and are also stayed together by means of one, two, or more rows of tie rods.

Owing to the small span of the arches there is a considerable saving of bricks in the filling up of the spandrils in comparison with the original 10 feet span arch and girder system; there is less metallic area exposed, although from a structural point of view this system is very imperfect; almost the whole of the weight of the flooring is exerted on bolts, instead of upon the columns, as will be seen. Should a fire occur, the main bracket supports and lower flanges of the girders are exposed to its action.

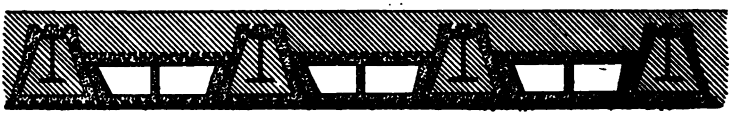
A most excellent system was patented by Mr. Hornblower in 1871 and 1873, in which wrought-iron rolled joists are placed at distances of 2 feet from centre to centre, and are cased in hollow skewback tiles of fire-clay, filled in with concrete, the interspaces being filled in with hollow voussoirs, and the whole floated with liquid cement or concrete.

The floors of the Manchester Pantechnicon and those of the Liverpool Corn Exchange are constructed on this system. (See Fig. 138.)

FIG. 138.



DETAIL



The system of Mr. Northcroft's, patented in 1876, is similar in some respects to the above. The principle of the system consists in the adoption of flat arches of fire-brick, specially designed to allow expansion and contraction.

The girders and other iron bonds are all protected, and, in conjunction with the wall plates, form a thoroughly united series of compound arches, with properly formed skewbacks on all four sides, the joints radiating from centre keys four ways.

The girders rest on turned rollers, and are bedded between skewbacks moulded to the contour of the girder (which is set in asphalte composite), thus allowing for the expansion of the girder when heated, without in any way weakening the stability of the floor. In this arrangement the full advantage of the tensile strength of the girder is obtained.

The section (Fig. 139) is constructed of 12-inch girders, the thickness of the floor being 20 inches, and the courses 6 inches deep, with spaces of 6 inches between them; these spaces are filled in with concrete or otherwise, the soffit is ceiled, and the floor is finished off with cement.

FIG. 139.

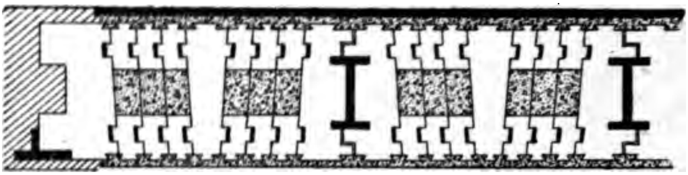


Fig. 140 is a transverse section of a floor, illustrating a method which the author recommended to Mr. Northcroft for protecting the main girders and columns.

The following table gives the safe loads (in cwts. per square foot) for Northcroft's system :—

| Clear Span in feet. | Rolled Girders, 32 lbs. per foot ; 3 feet centres. | Girders, 42 lbs. per foot ; 4 ft. 6 in. centres. |
|---|---|---|
| 18 | 2·75 | 2·60 |
| 24 | 1·60 | 1·50 |
| 30 | 1·00 | 0·90 |

Where lightness and economy in space are objects of importance, wrought-iron girders are generally used, although they form less rigid floors than girders of cast iron.

The late Sir W. Fairbairn devised a novel form of floor constructed of wrought-iron sheets in the shape of an arch resting on wrought-iron girders. The spandrils are filled up level with concrete and boarded.

Fig. 140.

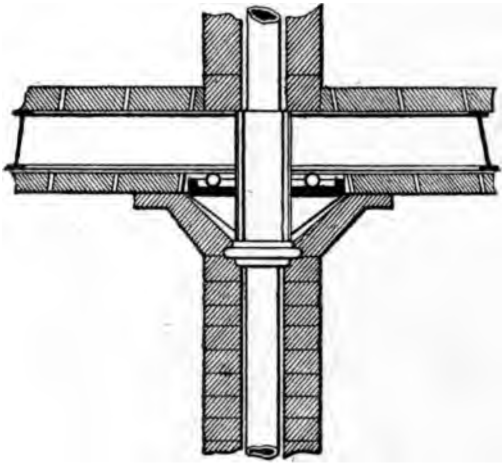
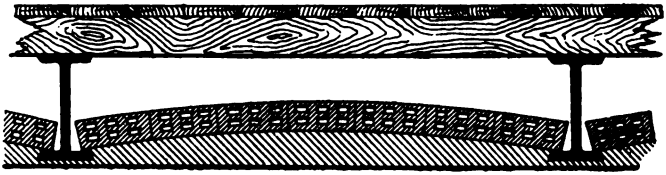


Fig. 141.



The system shown by Fig. 141 is extensively employed in Paris.

Wrought-iron girders are laid at distances apart which vary with the purposes of the floor.

Cross tie rods are placed 3 feet 6 inches apart, to take the tensile strain of the brick arches which are levelled up on the under side with plaster of Paris to form the ceiling; ordinary timber joists and boards are laid on the girders to form the floor.

This system was adopted by a Mr. Prichett, of York, in the construction of a retreat belonging to the Society of Friends.

This system is said to have withstood successfully the heat of a fire in Streatham Street, London, in 1862, which was caused by a tenant accidentally setting fire to the woodwork of one of the rooms. The floors prevented the fire from spreading.

### *Combination of Iron and Concrete.*

In a paper on "Fireproof Buildings" read before the Institution of Civil Engineers in 1853, Mr. Barrett described a system (invented by himself and Mr. Fox) as follows (see Figs. 142 and 143):—The substitution of girders and joists either of wrought or cast iron for those of timber, and the employment of concrete supported by and consolidated with the joists. The joists are fixed as the building proceeds. The floor is afterwards formed by first laying light rough strips of wood from joist to joist, bearing on the bottom flanges of the latter, and having narrow spaces between them; upon these is spread a layer of coarse mortar, which is pressed down between the strips, so as to form with them a rough and uneven surface for receiving the ceiling, the subsequent application of which thoroughly embeds the strips of mortar; a layer of concrete is then applied of the requisite thickness, for the purpose of ensuring the necessary rigidity in the floors. The ceiling is then attached by means of the hold afforded by the rough strips, and the coat of mortar is laid over and between them, being put on of such a thickness as to perfectly embed the flanges of the joists, and thus protect them from the action of the fire below.

Fig. 142.

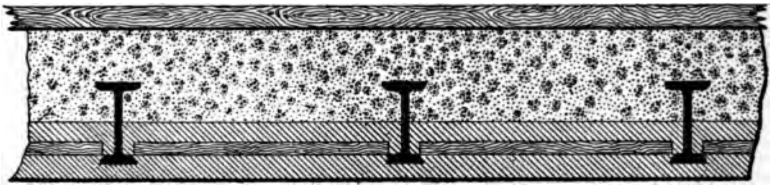


Fig. 143.

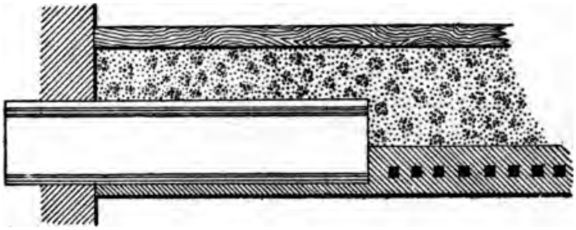
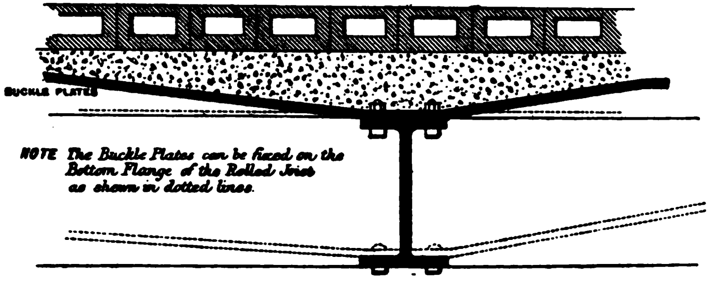


Fig. 144.



NOTE The Buckle Plates can be fixed on the Bottom Flange of the Rolled Joist as shown in dotted lines.

For the finished surface of the floor, besides the ordinary flooring boards, cements of different kinds, such as Portland, Kean's, Parian, and plaster of Paris may be used. The thickness of the flooring rarely exceeds 11 inches.

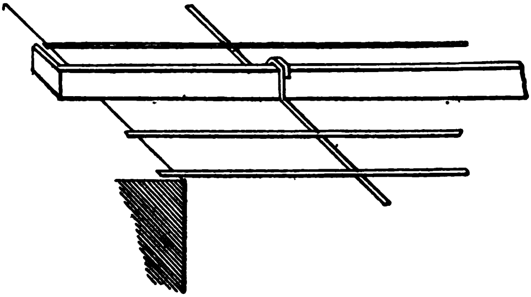
Fig. 144 represents a section of a form of floor invented by Mr. Robert Mallet, F.R.S., and is the strongest form of floor extant. It consists of wrought-iron joists supporting wrought-iron buckle plates, and to which they are bolted on the top of the buckle plates; concrete is applied, and the whole finished off, either with hollow paving bricks or joists and floor boards.

### *French Systems* (*Iron and Concrete*).

The substitution of iron in the place of timber for flooring joists in Paris is due to a carpenters' strike, which took place in that city in 1840. The masters, determined not to be outdone, employed iron and concrete in the place of the timber.

The systems of flooring most generally used in France are those known as the Vaux and Thuasné systems.

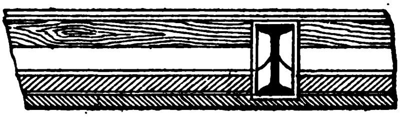
Fig. 145.

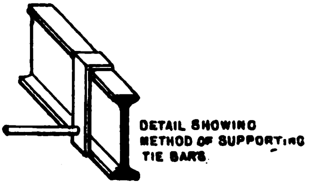


The former is a very simple, yet novel, form of construction—plates of wrought iron, bent as shown, being used for holding on the walls, and these plates being connected to each other by wrought-iron tie rods bent over the plates. (See Fig. 145.)

In the Thuasné system (see Fig. 146) rolled flanged joists, slightly arch-shaped, are used; these are placed 2 feet from centre to centre, and connected throughout their length at intervals of 1 metre, or 3 feet 3⅜ inches, by ties of flat bar iron placed on edge, and resting on the lower flange, the ends of the bars being turned over the top flange of the girder, and fastened one to another, either by wrought-iron straps or chains. Upon these ties are placed three square bars between each pair of girders and parallel to them from wall to wall, into which their ends are turned down and built on.

Fig. 146.





The ceiling is formed by throwing the plaster down on to a wooden platform, which is removed after the plaster is firmly set. This system was adopted for the floors of the Louvre in Paris, and was so proportioned with regard to strength, that the deflection of the floors under a load of 1·3 cwt. per superficial foot should not exceed three-quarters of an inch.

Allen's system, patented in 1862, consists in the special composition of the concrete, Portland or other cement being employed in combination with cinders, slag, coke, or clinkers. This material was subjected to a severe test in 1871, when a six-storeyed building erected for Messrs. Waterlow and Sons, in Finsbury, London, was partially destroyed by fire. In this building, Mr. Allen's improved concrete had been used for lintels over double iron doors in party walls, and over all doors and window openings. The iron doors, columns, girders, floors, and roofs, and all the ordinary stonework were destroyed, and the granite paving of the courtyard was considerably damaged. York landings, 8 feet by 3 feet and 6 inches thick, forming the sills under the iron doors, were entirely destroyed, while the concrete lintels above them, which had been exposed to a much fiercer heat, were quite uninjured. Messrs. Waterlow have in the construction of their new buildings employed this material on a large scale. The floors are formed of concrete 7 inches thick, and all the girders and ironwork of the floors are enclosed in the same material.

For ordinary purposes, Mr. Allen uses a proportion of 8 parts of clinkers to 1 part of cement, and for greater strength, a proportion of six of the first to one of the second.

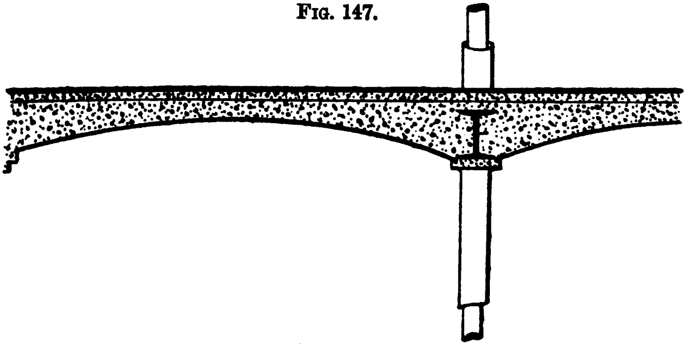
Dennett's system (see Fig. 147), which has been extensively adopted in England, consists in the employment of a concrete having gypsum or sulphate of lime for its base.

The other component parts consist of broken brick and rubbish screened so as to make it as clean as possible; or a certain proportion of stone debris, furnace dross, or clinkers may be used.

The concrete is spread upon sawn boards laid on ordinary ribs, which may in general be removed in three or four days after the concrete has been applied. The concrete acquires an extraordinary hardness, owing, no doubt, to the absorbent nature of its constituents. The arch form is generally adopted, the spandrils being filled in level, so as to form a horizontal floor.

This system has been lately adopted in the construction of extensive warehouses for the Great Northern Railway. These buildings were designed to carry the unusually heavy loads of from 4 to 5 cwt. per square

FIG. 147.



foot; the form of flooring is domical, rectangular in plan, 17 feet by 16 feet, rising about 20 inches in the centre, and being 7 or 8 inches thick at the crown. From a constructional point of view this system, in comparison with the cross-girder systems, such as Fox and Barrett's, has the disadvantages possessed by the brick arches; that is, danger from settlement of supports, and lateral pressure exerted; but as regards rigidity, strength, and economy in the use of iron, it is superior to the cross-girder principle of Fox and Barrett's system.

It is quite true that a stronger girder is required to carry a space of flooring, say 16 feet by 10 feet, than one 16 feet by 2 feet, the usual distance between the cross girders; but in the latter case a much lighter girder or joist must for the sake of economy be employed, than would otherwise be determined by such proportion between its length and depth as would be required to ensure rigidity. For the purpose of further illustration, let us assume that the exponents of the horizontal system would in such a case use joists 7 inches deep, and weighing about 20 lbs. to the foot, to carry a floor space of 16 feet by 10 feet, having a distributed load of 17½ tons.

Now to carry a floor space on Dennett's system would require one joist 12 inches deep and weighing 56 lbs. per foot. This would carry a safe distributed load of 19½ tons, thus showing a superiority of 12 per cent. extra strength, and a saving of 45 per cent. in the weight of iron; and with regard to rigidity, a most important consideration in floors which have to carry machinery, involving as it does questions of wear and tear, both of the structure and of the plant, the advantage of this system is still greater.

The ratio between the intermittent deflection of a 7-inch and of a 12-inch rolled joist, the length of the two being equal, would be greater than the simple inverse ratio of their dimensions.

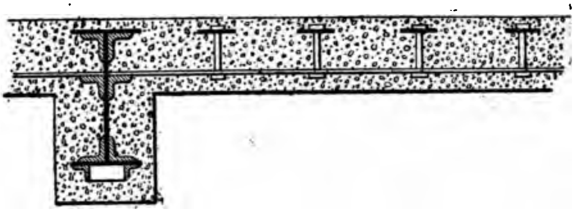
To ascertain the strength of the arches constructed on this principle, the following experiment was carried out at the Manningham Mills, Bradford:—A 50-lb. cannon ball was dropped from a height of 28 feet on to the crown of an arch without causing the slightest damage, and also from a height of 56 feet with this result, that the shot was embedded in the brickwork of the arch, no damage being done to the arch beyond a radius of about twice the diameter of the shot.

In the latter case, the force of impact exerted by the shot on the few inches upon which it fell, was calculated at upwards of a ton.

In Hyatt's system (Figs. 148 and 149) the inventor utilises the power of resistance to compression which concrete possesses, in combination with the tensile strength of iron, by substituting for the ordinary flanged rolled girders, a tie rod of 2 inches by one quarter of an inch.

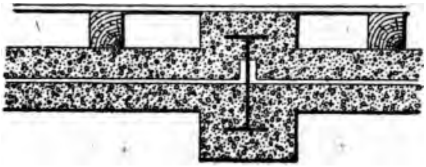
A series of experiments made on compound beams constructed on this principle, and varying in weight from 200 to 900 lbs. each, appear to be favourable to this principle of construction.

FIG. 148.



About fifty such beams were subjected to tests until broken. The tests were carried out by Mr. Kirkaldy, and from the results obtained the materials appeared to work very well together, and to furnish a perfect substitute for riveted or rolled beams.

FIG. 149.



The construction of floors upon this system is as follows:—

The girders rest directly on the main walls; to the under side of the bottom flanges are riveted angle-irons, which carry quarter-inch wires fixed crosswise for the purpose of holding the fire-resisting material.

The ceiling-holders, or blades of iron, which are 2½ inches deep and notched upon the ends so as to be readily slipped upon the flanges of the joist, are placed from 2 to 3 inches apart. The concrete is then filled in and around these blades, and light timbers are laid upon the concrete ceiling to nail the flooring to.

In this system the ceiling is made sufficiently strong to carry the load, in case the woodwork above it should burn away.

Another system of Mr. Hyatt's consists in the employment of flat tie-irons instead of wrought-iron flanged joists, the concrete in this case being the portion of the beam or slab that resists compression. These flat ties of iron are a quarter inch thick by 2½ inches wide, and are placed at a distance of 6 inches from each other.

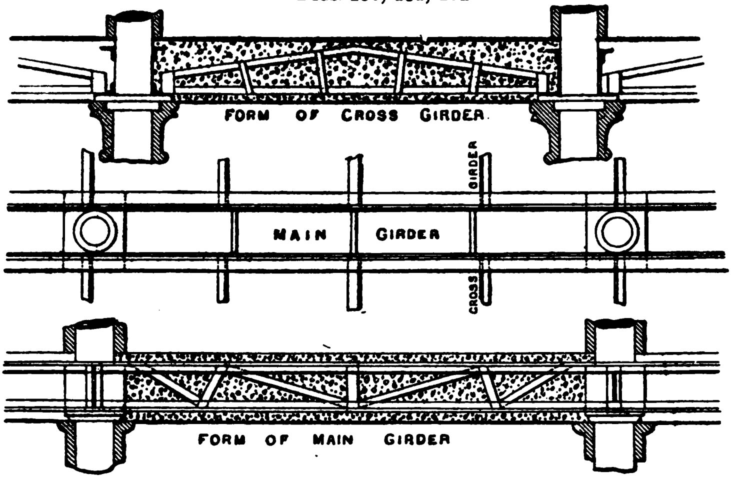
*Moreland's System.*—The main girders of this system are formed continuously from one end of the building to the other, and are made in two parts, and one is fixed on either side of the column; each of them is composed of a single angle iron, and braced with angle bars. The main girder is an open braced parallel girder 15 inches deep, the concrete being 2¼ inches thick on top and bottom, so that these girders are completely immersed in a concrete block. For cross girders, bow-string girders are placed, one over each column, and three between, and are placed about 3 feet 9 inches apart. The bow-string cross girders are composed of angle irons for the top and bottom flanges with flat iron connections.

The great advantage of this open girder arrangement is, that the block of concrete is not separated by the webs of either the main or transverse girders, but adheres through the braces; an effectual coherence is thereby obtained, and the whole of the iron composing the floor is immersed in one solid block of concrete, from one end of the structure to the other. This floor is calculated to carry immense loads.

In the Figs. 150, 151, 152, on this principle, the main girders are 15 inches deep, the cross girders are 10 feet 9 inches long; the main girders are placed 12 feet apart from centre to centre, the cross girders are 3 feet 9 inches apart. This floor is calculated to carry a load of 3 cwt. to the foot superficial.

The author is indebted to the kindness of Mr. Cates, F.R.I.B.A., for the following notes by Mr. Pedder.

Figs. 150, 151, 152.



The latter gentleman, who has had considerable experience in the construction of fire-resisting structures, states that he built a block of buildings containing twenty-four rooms, entirely of the refuse of spelter works, such as old retorts, &c., ground up, three parts of such materials being mixed with two parts of sand and one of Portland cement, the whole thoroughly mixed in a dry state, and turned over at least four times with the shovel, after the addition of the water, and bonded with flat pieces of burr, slag, &c.

The floors and roof are formed as follows: for the soffits (forming the ceilings of the rooms beneath) equal

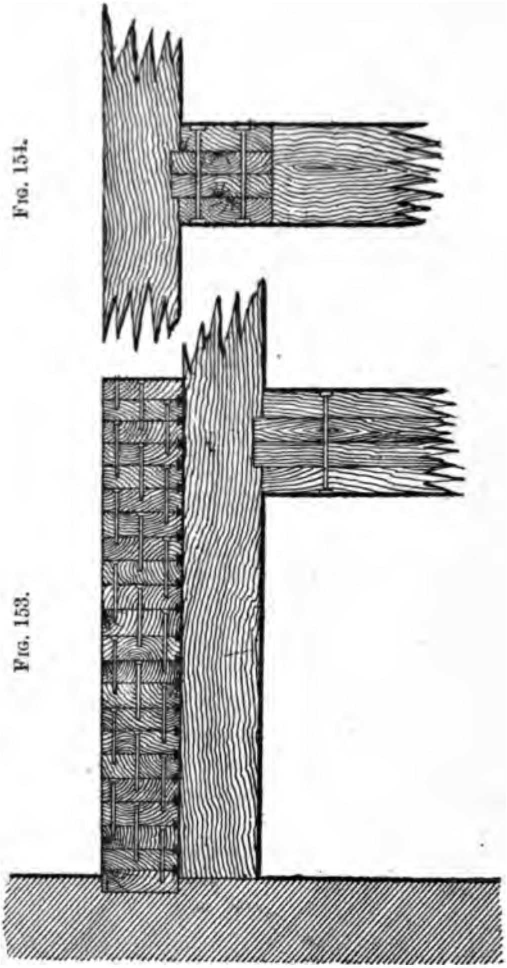


FIG. 154.

FIG. 153.

parts of ground ballast and cement; for the body of the floors, two parts of rough burnt ballast, such as the out-throw from sieves, one part of sand, and three of cement; on this was placed a layer of small pieces of slagstone chips, well trodden in and well mixed together, the whole being finished with a mixture of one part of fine ballast, one of sand, and two of cement.

### *System of Fire-resisting Timber Flooring.*

Evans and Swain's system (see Figs. 153 and 154) consists in the employment of ordinary timber joists of uniform depth, generally from 4½ inches to 11 inches for ordinary floors and with spans up to 30 feet, but deeper where greater span or strength is required, and of any thickness, the thinner the better, as there is less chance of their shrinkage or the formation of open joints.

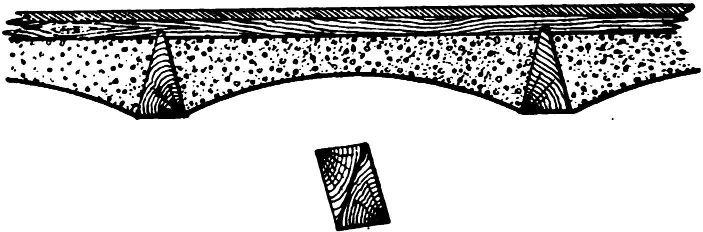
The joists are placed in close contact, the ends bearing on the walls in the usual way, only in this system no wall plates are required.

The sides of the joists are brought into intimate contact by being spiked together at intervals with jagged spikes or screwed with ordinary screw bolts. The spikes or other fastenings are placed 18 inches apart and fixed alternately. Each joist, previous to being fixed, is prepared for receiving plaster by having an angular groove run on each side of the bottom edge, so that when the joists are brought into position, the grooves form a series of dovetails on the under side of the wooden floor or ceiling. These dovetails form a key, and the ceiling is then plastered in the ordinary way with a good thick coat of common plaster.

### *Combination of Wood and Concrete.*

In building the offices of the Board of Works, London, Mr. Marrable, the architect, adopted a novel and ingenious method of construction: it consisted in cutting the beams for the joists diagonally so that the joists were of a wedge form, and when laid at distances of 18 inches apart and the space filled with concrete, the beams fulfilled the properties of skewbacks, and supported the concrete. (See Fig. 155.)

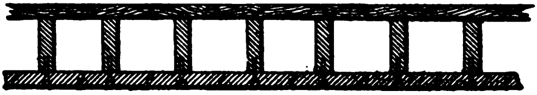
FIG. 155.



SECTION. SHOWING MANNER OF CUTTING BEAM DIAGONALLY

Fig. 156 represents a system of timber flooring suitable for the floors of workmen's cottages. This system of flooring is, for all practical purposes, fire-resisting; it is sound-proof, and at the same time exceedingly strong.

FIG. 156.



As will be seen, each joist is built up in the form of a ⊥ girder, and it has all the excellent constructional qualities of that form of girder. Each girder joist butts close up against the other.

A floor of this form of construction combines lightness with economy in space. The ceiling could be painted with silicate paint in lieu of plastering.

A floor thus formed, a fire would most probably char the timber, and the charcoal would resist the conduction of the heat in proportion to its thickness, and the floor would not be detrimentally affected by the water which might be thrown upon it, should a fire occur.

This system is especially valuable for small buildings liable to alterations.

### *Enumeration of the defects inherent in the various fire-resisting systems described, showing how they may be remedied.*

Brick groined vaulting on piers of the same material.—Although perfectly fire-resisting, this system is too massive and heavy for all but basement floors.

Combination of cast iron and bricks.—The form of the main girder employed in this system is practically the worst that can be adopted in respect to the quality of fire resistance, as the lower flange of the girder is generally unprotected. In order to render this system at all effective, all the girders should be completely encased in some refractory material, such as fireclay, concrete, &c. All brick arching should be of a minimum thickness of 9 inches.

The employment of ordinary mortar is not to be recommended, especially at the joints of the soffit, as the action of fire would soon destroy the adhesive properties of ordinary mortar. An excellent mortar for the purpose is made by mixing pozzuolana, or calcined fireclay, with freshly-ground lime; three-fourths of the former should be added to one-fourth of the latter. The substance should be mixed dry, in the first instance, and the mixture rendered plastic by the addition of soft water.

Messrs. Dennett's and Hornblower's systems are both perfectly fire-resisting. In all instances where iron is used, preparation for possible expansion should be made.

Mr. Northcroft's system is very perfect, as it is capable of resisting the most intense heat. Allowance in this system is made for expansion and contraction, both in the iron and brick.

The system has, however, the disadvantage of being very expensive, and requires exceedingly careful supervision in its construction. The system is admirably adapted for the roofs and floors of safe-rooms and for rooms containing highly inflammable substances.

The French system (Fig. 141) is very defective. The fire can burn downwards through the light wooden joists and floor boards, and may heat the girder and cause it to collapse. The spandrils of the arches should be filled up level to the under side of the floor boards with some refractory material, such as fireclay, concrete, &c.

### *Combination of Iron and Concrete.*

In Fox and Barrett's system the rolled joists are encased with concrete, but the main iron girders are unprotected. This defect should be remedied.

The concrete, as ordinarily applied, is not fire-resisting. This defect also applies to the Vaux and Thuasné system. The aggregate should be calcined.

The French systems (Vaux and Thuasné) are very defective, both in respect to fire resistance and economy in construction, as there is no protection from heat applied from above the floors disastrously affecting the rolled iron joists, while in respect to construction, its complex and unstable character renders it expensive and quite unsuitable for rooms containing machinery.

Dennett's system.—In this system, as originally applied, the lower flanges of the rolled iron joists were exposed. This defect has, however, been remedied in numerous late applications of this system. In the construction of a warehouse and mill at Belfast, which was completed in 1877 for the Brookfield Linen Co. (see Fig. 147, page 221), all the ironwork is completely encased in concrete.

Dennett's system has been employed for the floors of the New Law Courts, London, and many of the most important modern buildings in England. The system undoubtedly possesses many excellent qualities, combining lightness with strength, and being capable of withstanding very high temperatures.

If the concrete is heated and brought into contact with water it may, however, disintegrate; therefore this fact should be borne in mind in extinguishing any fire which may occur in buildings constructed on this system—the water should not be thrown on to the under side of the arches.

Hyatt's system.—Mr. Hyatt states that he has invented a fire-resisting cement. If a material possessing such a quality be used, his system is excellently adapted for rooms where light flooring is desired. The intrinsic structural qualities of both wrought iron and concrete are utilised, in the former, the tensional strength, and in the latter, the resistance to compression. All the iron is encased with concrete.

When ordinary concrete arching is used, a good method of protecting it from the effects of heat, and at the same time adding to its strength, is to use corrugated galvanised iron sheets under the soffit of the concrete and placed from girder to girder, thus constituting an arch of great strength, and in the process of construction serving the purpose of centres—a great convenience. Sufficient play must be allowed for expansion in case of fire, with this precaution; even assuming the iron sheets to be intensely heated, the real strength of the concrete would not be affected.

The great strength possessed by corrugated sheet iron, arranged in arch form, is owing to the principle of the corrugations, which are equivalent to so many small arches, imparting immense strength and rigidity to the sheets.

Moreland's system is a most perfect combination of iron and concrete, and is well adapted for warehouses where floors of great strength are required.

### *Timber System.*

Evans and Swain's system has unquestionably many excellent qualities, viz. its lightness and strength, and the small coefficient of expansion. Moreover, it possesses one distinct advantage over other systems; however highly timber is heated, the contact with water will not destroy its adhesive strength.

Captain Shaw, the Superintendent of the London Fire Brigade, speaks highly (and from experience) of the fire-resisting qualities of timber, when properly applied for constructional purposes.

Messrs. Evans and Swain publicly experimented on their system in 1877, the results of the experiment being considered very satisfactory.

In the construction of this system of flooring the timber must be properly shrunk. Shrinkage of the joists would prove disastrous in case of fire in warehouses containing cotton or other inflammable materials, as a spark carried by the smoke through one of the crevices, caused by the shrinkage of the wooden joists, would be sufficient to set fire to such inflammable material.

### *Intermediate Floor Supports.*

Brick piers are most suitable for supporting ground floors, but are inapplicable where continuous supports are required for several floors, and cast-iron columns are usually employed. As a rule, there is no preparation for protecting the columns; this is a very serious error, because, assuming the floors are constructed to resist the effects of fire, should a fire occur there is great danger of the columns becoming heated and eventually collapsing, thus causing the destruction of the entire structure.

In the construction of the National Safe Deposit Company's Building, London, Mr. Whichcord, the architect, remedied this defect by encasing all the cast-iron columns in fireclay. Figs. 157 and 158 represent Hornblower's system of protecting columns and girders.

Mr. Northcroft, at the suggestion of the author, also employs a method of encasing the columns with fireclay blocks. (See Fig. 140, page 215.)

Fig. 157.

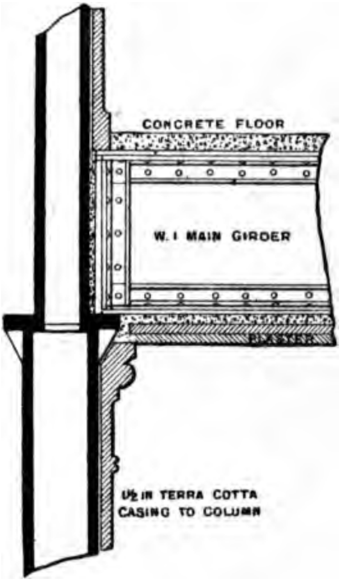
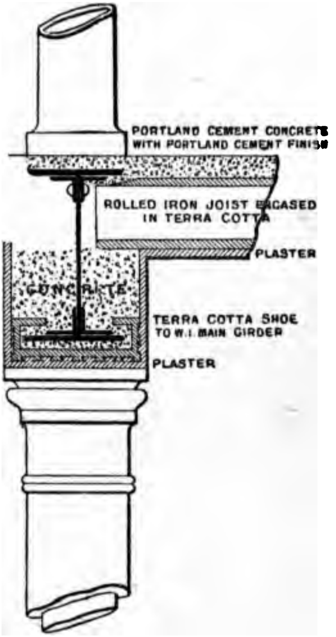
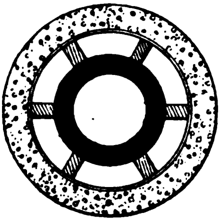


Fig. 158.


PORTLAND CEMENT CONCRETE WITH PORTLAND CEMENT FINISH
ROLLED IRON JOIST ENCASED IN TERRA COTTA
PLASTER
CONCRETE
TERRA COTTA SHOE TO W. I. MAIN GIRDER
PLASTER

Messrs. Dennett have lately commenced to encase the cast-iron columns in their special concrete. The manner of fixing is as follows: strips of corrugated hoop iron are fastened in a vertical position round the column, and the concrete is then applied to a thickness of from three to four inches in thickness. An experiment was made at Nottingham to test the value of this method of protecting columns. A cast-iron column, encased as described, was placed on a fire of wood and shavings saturated with gas tar, and allowed to burn with a fierce heat for a space of 4½ hours; when half the time had elapsed, the column was thrown over, so as to lie horizontally in the fire, and have its whole length exposed to the flames. The fire was at length extinguished by water, and on examination the concrete was found to be intact, and the column cool enough to allow handling. (See Figs. 159 and 160.)

Fig. 159.



Messrs. Moreland and Sons apply concrete to columns in the following manner. Sheet-iron cylinders are made in three segments working on hinges; the cylinders are placed round the columns with a space of about three inches between the interior of the casing and the outside of the column; in this space is poured the concrete, cement or plaster; when the material is set the casing is removed.

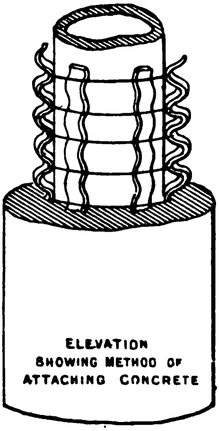


Fig. 160.

Messrs. Evans and Swain employ wooden posts for supporting their flooring, but instead of using solid balk timber, they build up or form their posts of a series of thin timbers arranged side by side and closely bolted or spiked together; by this means they avoid the exposure of large knots. As a further protection from fire, the pieces composing these posts are grooved similarly to the floors, and the whole is covered with a good coat of plaster. This system of supports is practical for one storey, but not for several storeys.

It is a common practice to make each cast-iron column independent of the others above it (see

FIG. 161.

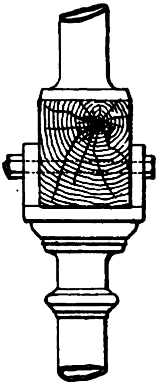
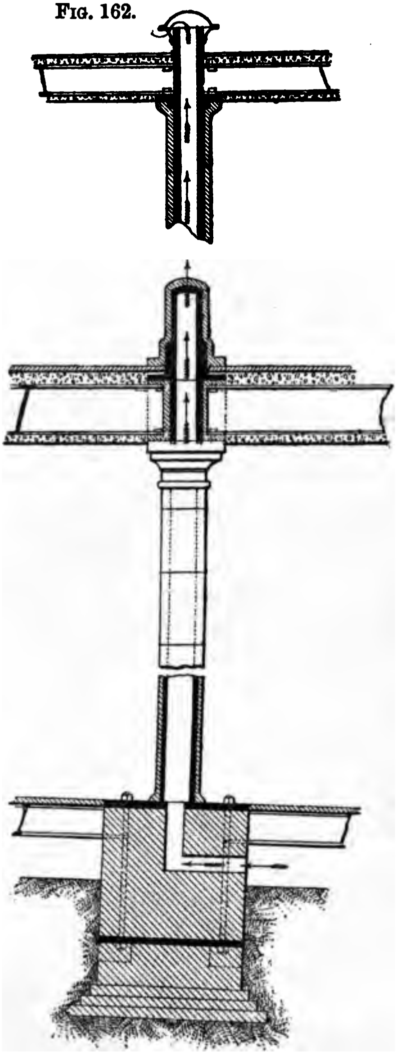


Fig. 161), each having its respective base-plate. This method, both in respect to fire resistance and construction, is palpably defective: cast-iron columns should be connected in such a way as to form a

FIG. 162.



continuous column — without the intervention of any plates between the base and the summit—so that a current of air could pass up the centre of the column; in case of fire, assuming there is an inlet for the air to enter the interior of the column at its base, the air would thus pass up the centre of the column at a velocity proportionate to the heat of the fire, and therefore would prevent the fusion of the iron.

Fig. 162 represents an arrangement for protecting cast-iron columns from the effects of heat. As will be seen, the column is encased with terra-cotta blocks, and is continuously hollow from basement to roof, so that should a fire occur, the air currents (induced by the increased temperature) passing up the interior of the column, would prevent the column from becoming overheated. The columns, before being erected, should be coated both internally and externally with Dr. Angus Smith's liquid pitch composition to prevent corrosive action.

### *Walls.*

The external walls of industrial buildings are usually built solid: this is a mistake, as, should fire occur, the heat would penetrate through the wall, calcining the mortar, and destroying its adhesive qualities. All external walls should be built double, with a cavity of at least two inches between the inner and outer walls. The inner shell should be of brick, but the external shell may be of any material desired. The two walls should be well bonded together with hoop iron, or better still, header fireclay bricks, eleven inches long. (See Fig. 163.)

In forming the window and door openings, the reveals should be so constructed as to protect the side frames of windows and doors from the effects of fire. It is desirable that the window frames should be of iron.

If ornamental stone, granite, or marble window and door-heads are desired, the treacherous nature of these materials should be guarded against, by turning over them relieving arches to support the weight above.

This would prevent the danger which would otherwise follow from the unreliable nature of stone, marble, or granite when exposed to fire (see Fig. 164). Party-walls should be carried at least three feet above the roof; this would be an efficient protection against conflagrations in adjoining premises.

FIG. 163.

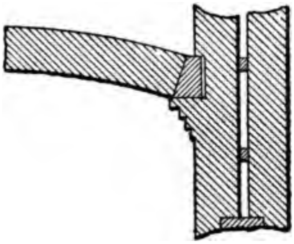
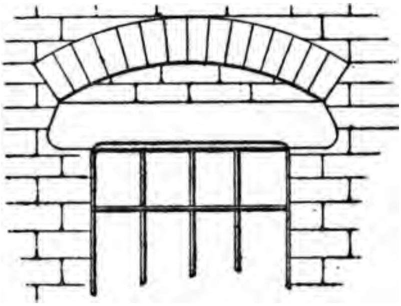
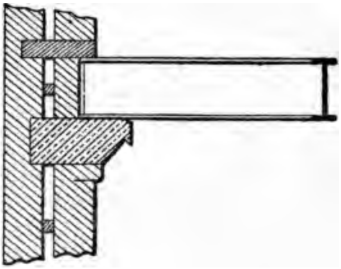


FIG. 164.



In fixing girders and brick or concrete arches into external walls, preparation should be made for possible expansion and contraction. Both girders and arches should rest on corbels or projecting brick courses; they should in no instance be built solidly into the walls. A good plan for providing a fit expansion and contraction is shown in Fig. 165.

FIG. 165.

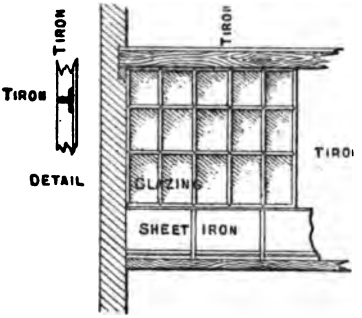


### *Partition Walls.*

The French system of constructing partitions to resist fire is as follows. The frames, braces, and quarterings are constructed in the usual way of timber filled in between with rough stone rubble; the surfaces are lathed with strong oak laths, two inches or three inches wide, and placed four to six inches apart; a coat of plaster is then applied simultaneously on each side, and pressed through. The plaster thus fills up the vacuities, and the rubble is rendered solid and compact. This plastering is put on thick enough to cover the timber and laths, and to form a continuous and concreted body of material rather than as filling-in merely. Ceilings are commonly constructed in a similar way.

By the subdivision of floors by means of partitions into separate apartments, fires might be so isolated that time would be afforded for the escape of the operatives, and for the removal of any goods from the other subdivisions; moreover, the smallness of the area would prevent any rapid or disastrous results; and the fire could be closely approached and extinguished without damage to the goods in the other divisions.

FIG. 166.



A system of partition has lately been introduced by a Mr. Booth, a smith of Bolton, and is especially applicable to buildings where light is valued. The form of construction is shown in Fig. 166; light wrought-iron framing filled in with glazing.

This partition is also used for isolating dust-producing machinery.

In warehouses where large areas are requisite, Bunnett's wrought-iron curtains should be used, so that in the day they might be coiled up so as to be out of the way, and lowered at night, the columns acting as the curtain guides.

### *Roofs.*

The eastern nations of antiquity utilised their roofs for the purposes of prayer and repose; the roofs were therefore constructed on a horizontal level. The method of construction consisted in the application of layers of some fibrous substance, with intervening layers of resinous matter, and finally covering the whole with earth and sand. A system of roofing almost the same as the above is still adopted at Treveley in Spain, at an altitude of 8500 feet above the sea; the roofs are formed with resinous layers mixed with birch bark, with a final surface covering of earth. In Norway a similar system is adopted; the roofs, however, are slightly inclined. These roofs, from the peculiarity of construction, are well adapted for resisting fire, but, with the exception of the masonry vaulting of the freemasons, all the systems of roofing adopted by other European builders were of timber, and slated or thatched; both systems extremely defective as regards fire resistance.

The first modern attempt to construct a roof for secular buildings that would resist fire was made by Mr. Hausler, a Silesian merchant, in 1839.

He first applied his invention to several of his own houses. Hausler allowed several years to elapse to fully test the value of the system, and its success led to its extensive adoption.

Eventually, in 1850 a committee was appointed to test the efficacy of the invention, especially as to its resistance to fire.

The Committee issued their report in 1850, which stated that Hausler's fire and water safe roofing was a success, and had perfectly withstood the tests to which it was submitted. So satisfied was the Provincial Insurance Society of Breslau with the qualities of the invention, that they determined in 1859 to classify all roofs covered with Hausler's composition as fireproof. Some time after, the Saxon Government instituted a series of experiments with Hausler's system to test its fire-resisting properties.

The success of the experiments induced the Saxon Government to repeal the law which prohibited the use of Hausler's composition.

The *modus operandi* is as follows. The beams or spars forming the roof are placed 2 feet 6 inches apart, and fixed to the required pitch or inclination; the boarding must be fixed to the under side of the spars. Care must be taken that the entire surface of the boards presents an even surface.

The boards are now strewn with fine sand; after this stiff paper is laid over the whole of the surface, each layer lapping over the other. Hausler's composition, which must be heated in a pan or boiler until it becomes liquid (but not boiled, else it loses its adhesive properties), is evenly applied with a soft brush over the surface of the paper, and another layer of paper quickly applied, followed by an application of the composition until four layers of paper and composition are completed; the last layer of composition must be considerably thicker than the rest, and covered with powdered small coal, and on the top of this, fine and coarse gravel to a depth of some inches: the latter must be beaten down to a uniform level, and finally covered with asphalte.

In England wrought-iron roofing is commonly employed of the forms shown by Figs. 167 and 168; but it will be evident that, in case of fire, the expansion of the wrought-iron tie bars would drive out the walls, and with greater heat, the tie bars would give way altogether.

Fig. 167.

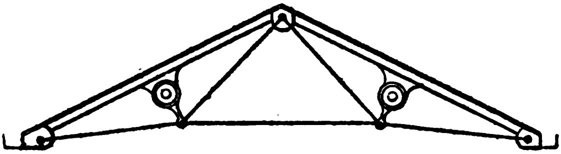


Fig. 168.

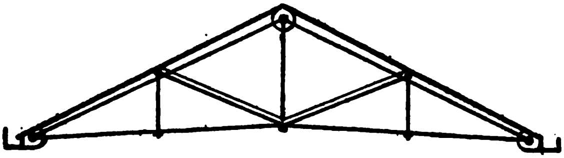
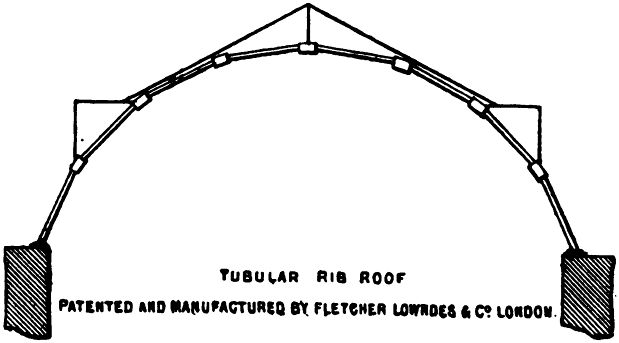


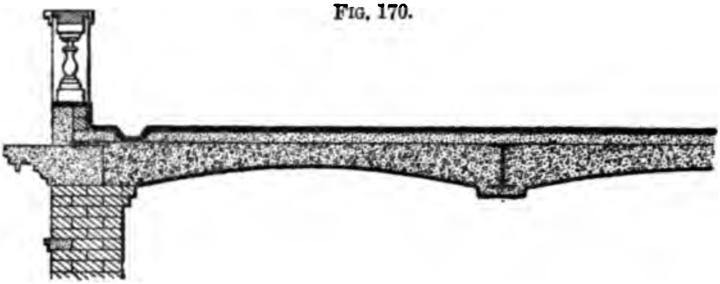
Fig. 169.



A better form of roof, admirable in all respects, is shown by Fig. 169.

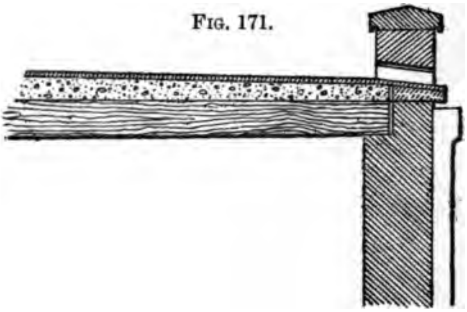
In 1867, a large warehouse in the West India Dock was destroyed by fire. The roof was of wrought iron and supposed to be fireproof. During the fire, however, the iron rafters and tie bars expanded and then fell; in expanding, the roof almost pushed the walls over; had the walls fallen, the fire would probably have extended to the other warehouses on the quay.

FIG. 170.



Messrs. Dennett employ for roofs, a modification of their system of flooring, covered with pyrimont Seyssel asphalte. (See Fig. 170.)

FIG. 171.



The objection to the flat systems of roofing is their retention of water, destroying, as it eventually does, the asphalte covering. To produce a quicker removal, the concrete should be formed into valleys and ridges, as shown in Fig. 181, page 265, and more numerous outlets to fall-pipes should be provided.

Messrs. Evans and Swain's system of roofing is shown in Fig. 171; the timber is covered with concrete, and finished off with cement.*

### *Doors.*

Sheet iron is a material which is commonly employed for fire-resisting doors, and is specified in the Metropolitan Buildings Act, but sheet iron will not withstand the heat of even a moderately large fire. Some time since, Messrs. Cocker's new warehouses were destroyed by fire. Mr. Chubb, the famous safe manufacturer, who visited the premises after the fire, states that the conflagration originated in a

FIG. 172.

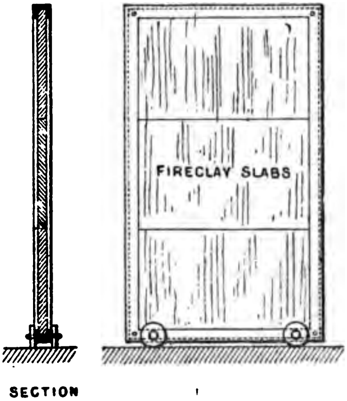
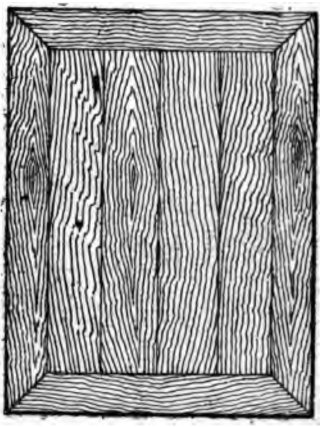


FIG. 173.



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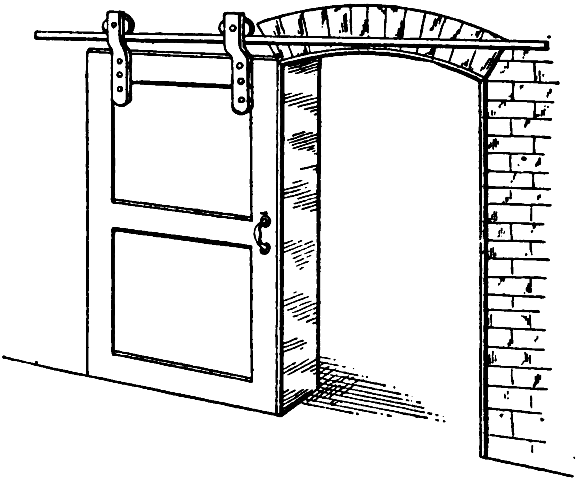
* Lately, in designing a fire-resisting roof, the author adopted the following plan. The tie rods of principal trusses are covered with asbestos. Instead of timber purlins, light wrought-iron T-irons are used, resting upon the lower flanges of the rafters of principal trusses, which are formed of rolled joists. Concrete is filled in between the T-iron rafters, the under surface finished off with Parian cement; but, if desired, plaster or boarding could be used; the upper surface of concrete can either be finished off with slates or asphalte.

new block of the buildings, which was almost completed, and that there appeared to have been on each floor a pair of sliding sheet-iron doors, designed with the intention of separating the new block from the rest of the building, in accordance with the requirements of the Building Act.

These doors were found to be bent and distorted, and in all cases had fallen amongst the debris, thus fully proving their utter inability to resist heat. Further, in the great Tooley Street conflagration the wrought sheet-iron doors prescribed by the Metropolitan Building Acts proved to be utter failures.

FIG. 174.



Doors may be constructed of slabs of slate or fireclay, set in wrought-iron frames (see Fig. 172). If of timber they should be of oak or teak, as, according to Professor Hosking, these timbers stand the highest as regards resistance to fire. The timber doors should be at least 2½ inches thick and formed as shown in Fig. 173, the frames mitred so as not to expose the cross section of the wood.

The doors, which should slide, should also be provided with weights so as to ensure self-closing action.

Mr. Lascelles, a London builder, has erected structures in which the frames of the doors and windows, as well as the walls, floors, and roofs, are constructed of concrete.

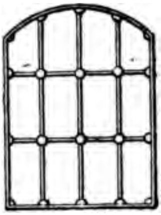
Fig. 174 represents Bunnett's patent wrought-iron fire-resisting sliding-door, and is well suited for its purpose.

### *Windows.*

All window-framings should be of iron, protected from rust by means of Barff's magnetic oxide. If they are made of wood, they shrivel up as soon as the flames reach them. A simple and inexpensive window-frame can be made by using light sections of T iron similar to the manner of forming light partitions shown in Fig. 166, page 238.

Harris's patent wrought-iron windows are simple and inexpensive; they are manufactured by Whenman and Co., 90, Cannon Street, London, E.C. (see Fig. 175). Moline's patent wrought-iron window-frames are also worthy of mention, as also those of Burt and Potts, Westminster.

FIG. 175.



The main styles of the frames should be built in deep reveals formed in the window jambs.

In warehouses for containing goods of immense value, each window should be provided with a wrought-iron shutter, which should be lowered every night on closing the warehouse. In case of fire, such a provision would effectually cut off the oxygen supply and the fire would thus be smothered. Moreover, should a fire occur in adjoining premises, there would be no danger of the flames or sparks entering and propagating it. A fire which occurred in 1863 conclusively proved the value of the shutter arrangement. The following is an account of the fire.

" The large and handsome warehouses of Messrs. J. and R. Morley is situate at the corner of Gresham and Wood Streets, overlooked by a large window on the ground floor at the back, the little court in which the fire originated, and to which it was at first confined.

" This large window was protected by a revolving iron shutter, and that more against robbery than fire. On this occasion for some time the flames played fiercely, but harmlessly, about the outside of the window so guarded by the iron shutter. Had they once entered Messrs. Morley's premises at that point, the stock insured inside, and estimated at 250,000*l.* to 300,000*l.*, would inevitably have been destroyed, if, indeed, the devastation would have ended in that one vast pile of buildings. Upon such a slender condition of safety did property, almost fabulous in value, and belonging to a single firm, depend in this case."—*Times*, 22nd December, 1863.

Messrs. Bunnett and Co.'s revolving shutters are well adapted for this purpose.

### *Stairs.*

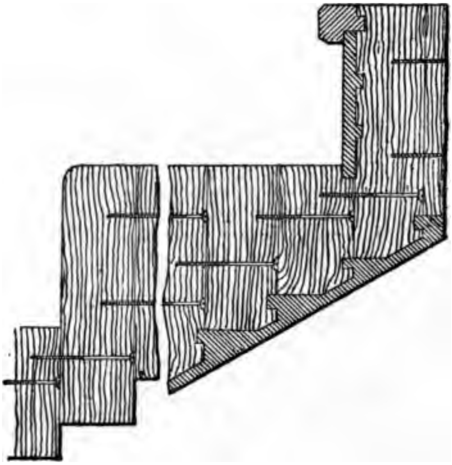
The French method of constructing fire-resisting floors is as follows. Wrought-iron carriages are used of an L shape, the upper edge being cut to the requisite number of steps. The risers are formed of thick sheet iron and are fixed to the carriages with angle plates and bolted.

The soffits are formed by iron bars placed below the risers, and fastened to the carriages on these bars: thin iron rods are laid, and this skeleton carries the plaster, which is generally filled up solid, to the under side of the treads, which may be of slate, terra-cotta, brick, stone, or marble.

The landings are formed by iron joists, bars, and rods, covered with plaster concrete.

Messrs. Evans and Swain employ steps composed of a series of joists, or thin timbers, screwed or spiked together, and, if necessary, they are grooved, and the soffits covered with plaster. (See Fig. 176.)

FIG. 176.



If stone is used for the construction of stairs, it should be supported at both ends, and not on any account be supported at one end only. The best material for steps is fireclay or vitrified blue clay.

For manufactories, the stairway should be constructed in towers projecting from the building, as shown in Figs. 180 and 181, pages 264 and 265.

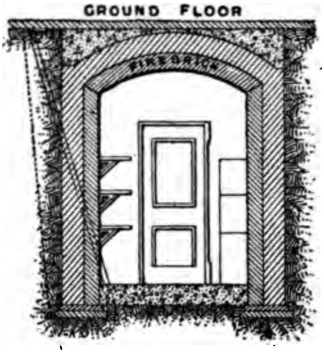
This isolation would be especially valuable in case of fire, as it would be practically safe, and would offer little danger to the descent of the workpeople. Moreover, there would be less probability of the stairway becoming a means of propagating the fire, especially if the midway door was fixed in the stairway between each floor, as shown in Fig. 180, page 264. Fires have often been spread by the heated vapour and sparks passing up the stairways and into the rooms above.

The water mains and hydrants should be fixed in the stairways.

### *Safe-Room.*

The safe-room should be located in such a way that, if a fire occurred with the worst results, the falling walls, beams, &c., should not disturb its position; therefore, the best situation for a safe-room is below the basement floor; it should be constructed of the form shown in Fig. 177; the walls of bricks, made of fireclay, or other refractory material; the roof arched with the same material; the walls should be at least 9 inches thick; as to the safes, the best makers are Chubb, Milner, and Chatwood. The safes of these makers are unsurpassed in respect to fire resistance, and are splendid examples of mechanical ingenuity.

FIG. 177.



## FIRE-RESISTING CONSTRUCTION.

### *Useful Formulæ and Tables.*

### CAST-IRON GIRDERS.

A = Area of bottom flange in inches.
D = Depth of girder in inches.
L = Length of bearing in feet.
W = Breaking weight in tons in the middle.

Then $W = 2\frac{A\,D}{L}$ Breaking weight in tons in the middle.

Area of top flange should $= \frac{A}{3}$ when the load is on the top.

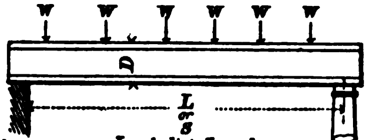
„ „ $= \frac{A}{6}$ „ „ on the bottom flange.

Safe load when stationary $= \frac{W}{5}$.

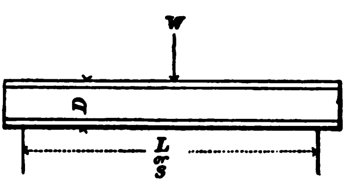
„ „ moving $= \frac{W}{8}$.

Proof load should not exceed $\frac{W}{3}$.

FIG. 178.



*Load distributed*



*Load in the middle*

A = Area of bottom flange in inches.
D = Depth of girder in inches.
L = Length of bearing in inches.
W = Breaking weight in tons.

Supported at both ends with load distributed $W = \frac{50\,A\,D}{L}$.

Safe allowable deflection $\frac{1}{40}$ of an inch for each foot of span.

$\frac{W}{3}$ for factor of safety.

TABLE OF BREAKING WEIGHTS OF CAST-IRON GIRDERS.
(In tons distributed.)

| Span. | Depth. | Size of Bottom Flange. | Breaking Weight. | Size of Bottom Flange. | Breaking Weight. |
|---|---|---|---|---|---|
| ft. | in. | in. in. | tons. | in. in. | tons. |
| 10 | 10 | 6 × 1¼ | 31 | 8 × 1¼ | 41 |
| 15 | 15 | 8 × 1½ | 50 | 12 × 1½ | 75 |
| 20 | 20 | 10 × 1½ | 62 | 15 × 1½ | 94 |
| 25 | 25 | 13 × 1¾ | 94 | 19 × 2 | 158 |
| 30 | 30 | 15 × 2 | 125 | 22 × 2 | 183 |
| 35 | 35 | 17 × 2 | 141 | 25 × 2 | 208 |

## WROUGHT-IRON GIRDERS.

General Remarks:—

Compressional strain may be computed at 4 tons per square inch.

Tensional strain may be computed at 5 tons per square inch.

Board of Trade Regulations, 5 tons per square inch in tension and compression.

### *Riveted Plate Girders.*

Rivets, 3 inches apart in the top.
" 4 " " bottom.

L = Length of girder or span in feet.
W = Weight distributed in tons.
D = Effective depth of girder in feet.
S = Strain on the top and bottom flanges at centre in tons.

$$S = \frac{W\,L}{8\,D}.$$

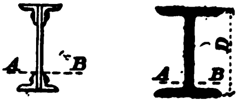
### FAIRBAIRN'S FORMULA.

A = Area of bottom flange in inches, part below A B (see Fig. 179).
D = Depth of girder in inches.
C = Constant.
L = Length of bearing in feet.
W = Breaking weight in tons in the middle.

When D is more than $\frac{L}{14}$, $W = C\frac{A\,D}{L}$.

C = 6·0 for plate girders.
C = 6·5 „ box girders.
C = 6·0 „ rolled girders.
C = 4·0 T girders.

FIG. 179.



### STEPHENSON'S FORMULA.

A and D as above.
W = Breaking weight in tons.
S = Span in inches.

Then $\frac{80\,A\,D}{S} = W$ {For girders supported at both ends, and with load in the middle.

$\frac{160\,A\,D}{S} = W$. As above, but with load distributed.

Area of the top flange = 1·18 A.

Depth of girder = $\frac{S}{12}$ or $\frac{S}{13}$.

TABLE OF STRENGTHS OF WROUGHT-IRON ROLLED GIRDERS; TRADE SECTIONAL SIZES; THE STRENGTHS FOR SAFE PERMANENT DISTRIBUTED LOADS. Based on the assumption that the iron in tension will break at 21 tons per square inch. The safe loads are taken at a quarter of the breaking weight.

| Weight of Girder per Foot Lineal. | Sectional Dimensions. | Bearing or Span in Feet. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
| | in. in. in. | Safe weights in cwts. | | | | | | | | | | | | |
| 5½ | 3 × 2 × 2 | 20 | 15 | 11 | 9 | 8 | 7 | 6 | 5 | | | | | |
| 7 | 4 × 2 × 2 | 27 | 23 | 17 | 13 | 12 | 10 | 8 | 7 | 4 | 3 | | | |
| 8 | 4¾ × 2 × 2 | 35 | 30 | 22 | 17 | 15 | 13 | 12 | 10 | | | | | |
| 11 | 6¼ × 2¼ × 2¼ | 69 | 50 | 38 | 32 | 28 | 23 | 20 | 19 | 17 | | | | |
| 12 | 5 × 3 × 3 | 86 | 62 | 48 | 42 | 36 | 30 | 27 | 23 | 20 | 18 | 14 | | |
| 14 | 7 × 2¼ × 2¼ | 96 | 72 | 55 | 47 | 38 | 33 | 30 | 26 | | | | | |
| 16 | 6¼ × 3¼ × 3¼ | 106 | 73 | 57 | 51 | 44 | 35 | 32 | 27 | 25 | 24 | 22 | 20 | |
| 19 | 7 × 3⅝ × 3⅝ | 136 | 101 | 78 | 67 | 57 | 50 | 44 | 40 | 35 | 33 | 31 | 28 | |
| 23 | 5 × 4½ × 4½ | 108 | 91 | 70 | 56 | 49 | 44 | 40 | 34 | 31 | 27 | 21 | | |
| 24 | 8 × 4 × 4 | 245 | 186 | 147 | 120 | 106 | 91 | 82 | 72 | 65 | 58 | 53 | 50 | |
| 24 | 9¼ × 3¾ × 3¾ | 263 | 206 | 163 | 131 | 115 | 102 | 86 | 78 | 71 | 64 | 58 | 53 | |
| 29 | 8 × 5 × 5 | 288 | 216 | 170 | 140 | 120 | 106 | 91 | 82 | 72 | 65 | 60 | 56 | 50 |
| 32 | 10 × 4¾ × 4¾ | 475 | 357 | 282 | 237 | 200 | 176 | 151 | 140 | 125 | 112 | 104 | 97 | 88 |
| 42 | 12 × 5 × 5 | 635 | 475 | 388 | 317 | 276 | 236 | 214 | 192 | 173 | 155 | 142 | 133 | 116 |
| 50 | 15 × 5 × 5 | 918 | 683 | 550 | 458 | 396 | 340 | 303 | 273 | 248 | 224 | 210 | 197 | 180 |
| 55 | 14 × 5½ × 5½ | 1013 | 768 | 611 | 509 | 480 | 382 | 342 | 303 | 277 | 252 | 232 | 213 | 190 |
| 56 | 12 × 6 × 6 | 950 | 726 | 567 | 473 | 413 | 357 | 318 | 280 | 252 | 238 | 218 | 200 | 185 |
| 57 | 16 × 5½ × 5½ | 1118 | 836 | 664 | 557 | 489 | 414 | 367 | 327 | 300 | 275 | 253 | 237 | 222 |
| 60 | 16 × 5⅜ × 5⅜ | 1020 | 900 | 665 | 565 | 490 | 420 | 380 | 340 | 310 | 280 | 260 | 240 | 227 |

## *Strength of Cast-iron Columns.*

### HODGKINSON'S FORMULA.

$W$ = Breaking weight in tons.
$L$ = Length of column in feet.
$D$ = External diameter of column in inches.
$d$ = Internal diameter in inches.

| Nature of Columns. | Both Ends Rounded when Length exceeds Fifteen Times Diameter. | Both Ends Flat when Length exceeds Thirty Times Diameter. |
|---|---|---|
| Solid cylinders of cast iron .. .. | $W = 14{\cdot}9 \dfrac{D^{3\cdot76}*}{L^{1\cdot7}*}$ | $W = 44{\cdot}16 \dfrac{D^{3\cdot55}}{L^{1\cdot7}}$ |
| Hollow cylinders of cast iron .. | $W = 13 \dfrac{D^{3\cdot76} - d^{3\cdot76}}{L^{1\cdot7}*}$ | $W = 44{\cdot}34 \dfrac{D^{3\cdot65} - d^{3\cdot5}}{L^{1\cdot7}}$ |

* Tables of 3·6 and 1·7 power.

| No. | 3·6 Power. | No. | 3·6 Power. | No. | 3·6 Power. |
|---|---|---|---|---|---|
| 3 | 52 | 10 | 3982 | 17 | 26892 |
| 4 | 147 | 11 | 5611 | 18 | 33035 |
| 5 | 328 | 12 | 7674 | 19 | 40133 |
| 6 | 632 | 13 | 10233 | 20 | 48273 |
| 7 | 1102 | 14 | 13367 | 21 | 57543 |
| 8 | 1783 | 15 | 17136 | 22 | 68033 |
| 9 | 2723 | 16 | 21619 | 24 | 93058 |

| No. | 1·7 Power. | No. | 1·7 Power. | No. | 1·7 Power. |
|---|---|---|---|---|---|
| 5 | 15 | 15 | 100 | 25 | 238 |
| 8 | 34 | 18 | 136 | 28 | 288 |
| 10 | 50 | 20 | 163 | 30 | 325 |
| 12 | 68 | 22 | 191 | 33 | 441 |

When the length is less than thirty times the diameter.

$W$ = Crushing weight in tons.
$w$ = „ „ of short column in tons.
$S$ = Sectional area of solid part of column in inches.

$$w = \frac{49 \,.\, W S}{W + 37 S}.$$

In hollow columns the thickness of metal should not be less than $\frac{D}{12}$.

### PROFESSOR GORDON'S FORMULA.

Take $L$ = Length in inches.
$W$ = Weight in tons.
$S$ = Sectional area of solid part of column in inches.
$D$ = Diameter in inches.

$$W = \frac{36\,S}{1 + \frac{L^2}{400\,D^2}} \qquad \text{Factor of safety} = \tfrac{1}{10}.$$

*Note.*—When girders are fixed in continuous lengths the joints should be made truly plane and perpendicular to the axis.

### TABLE OF HOLLOW CAST-IRON COLUMNS, AND SAFETY LOADS IN TONS.

Thickness of Metal in inches and a quarter.
Deduced from Hodgkinson's experiments.

| External Diameter in Inches. | Length in Feet. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| 4½ | 28·1 | 21·5 | 16·5 | 12·9 | 10·2 | 7·6 | 6·2 | 5·2 |
| 5 | 34·9 | 27·6 | 21·7 | 17·2 | 13·9 | 10·8 | 8·8 | 7·4 |
| 5½ | 42·1 | 32·6 | 27·5 | 22·3 | 18·0 | 14·6 | 12·0 | 10·0 |
| 6 | 49·4 | 41·0 | 33·6 | 27·5 | 22·7 | 18·8 | 15·8 | 13·4 |
| 6½ | 56·8 | 48·0 | 40·0 | 34·4 | 27·1 | 23·3 | 19·8 | 16·9 |
| 7 | 64·3 | 55·4 | 46·9 | 39·5 | 33·3 | 28·3 | 24·2 | 20·6 |
| 7½ | 71·8 | 62·7 | 54·0 | 46·0 | 39·3 | 33·5 | 28·7 | 24·8 |
| 8 | 79·3 | 70·2 | 61·1 | 51·7 | 45·4 | 39·1 | 33·8 | 29·4 |
| 8½ | 87·0 | 77·8 | 68·4 | 59·7 | 51·9 | 45·1 | 39·2 | 34·2 |
| 9 | 94·5 | 85·3 | 75·9 | 66·9 | 58·3 | 51·2 | 44·9 | 39·4 |
| 10 | 109·6 | 100·7 | 91·2 | 81·6 | 72·6 | 64·3 | 57·2 | 50·7 |
| 11 | 124·6 | 115·8 | 106·2 | 96·5 | 87·1 | 78·2 | 70·2 | 63·0 |
| 12 | 140·6 | 131·1 | 118·6 | 111·9 | 101·3 | 92·9 | 84·0 | 76·0 |

Thickness of metal = one and a quarter inch.

## PORTLAND CEMENT CONCRETE.

### *Form of Specification for Portland Cement (Grant).*

The whole of the Portland cement is to be of the best quality, weighing not less than 112 lbs. to the bushel, ground so fine that the residue on a sieve of 6400 meshes to the square inch shall not be more than 20 per cent. by weight; should the residue be greater, a quantity of cement proportionate to such excess must be added.

When brought upon the works it is to be put into a dry shed or store, having a wooden floor and all necessary subdivisions. The cement is to be emptied out on to the floor, the contents of every bag being kept separate, and is not to be used until it has been tested by samples taken from different sacks.

Testing.—The cement is to be gauged with three times its weight of dry sand which has passed through a sieve of 400 and been retained upon one of 900 meshes to the square inch. The cement and sand having been well mixed, about 10 per cent. of their weight of water is to be added and briquettes formed in moulds of one inch sectional area at the weakest part. The briquettes having in the meantime been kept in a damp atmosphere are to be put into water twenty-four hours after they have been made, and remain in water until their tensile strength is tested by means of a reliable apparatus and by an independent party.

All cement that when neat sets in less than two hours must bear, without breaking when subjected to this test, a weight of 142 lbs.; and if it takes from two to five hours to set neat, it must bear a breaking weight of 170 lbs. per square inch, twenty-eight days after the briquettes have been made; if not, it will be rejected and must be forthwith removed.

Tested neat.—The cement must bear a tensile strain of at least 400 lbs. per square inch after seven days, six of them in water, and 550 or 600 lbs. per square inch after twenty-eight days, twenty-seven of them in water.

The quality of the aggregate or ballast has a very important bearing on the success of concrete, so important that it is possible with the best cement to produce concrete of the worst description. The aggregate must be of a

A TABLE OF EXPERIMENTS AS TO THE STRENGTH OF CONCRETE ARCHING—DENNETT'S SYSTEM.

| Particulars of Arching. | | | | How Supported. | Particulars of Load. | | Total Weight. | Weight per Foot Support. | Result. |
|---|---|---|---|---|---|---|---|---|---|
| Thickness of Haunches. | Thickness of Crown. | Span. | Rise of Arch. | | Constituents. | Dimensions of Base of Stack. | | | |
| in. | in. | ft. | in. | | | ft. ft. | tns. cwt. | cwt. | |
| 10 | 6 | 8 | 8 | Supported on walls . | Load of cement in bags .. | 8 × 4 | 6 0 | 3¾ | No deflection. |
| 7 | 5 | 7 | 6 | Supported on walls . | Load of bricks .. | 8 × 6 | 8 10 | 3½ | No deflection. |
| 10 | 5 | 9 | 8 | Supported on walls . | Load of bricks .. | 5 × 5 | 6 0 | 4¾ | No sensible deflection. |
| 9 | 5 | 10 | 9 | One side supported by wall, the other by wrought-iron rolled joists .. .. | Load of bricks .. | 10 × 7 | 10 10 | 3 | No sensible deflection. |
| 10 | 5 | 7 | 6 | Supported on wrought-iron rolled joists .. | Load of pig iron . | 4 × 4 | 4 15 | 5¼ | No material deflection. |
| 10 | 5 | 7 | 6 | Supported on wrought-iron rolled joists .. | Load of kiln tiles. | 7 × 6 | 6 6 | 3 | No deflection. |
| 14 | 6 | 9 | 7 | One side supported by wall, the other by wrought-iron rolled joists .. .. | Load of bricks .. | 8 × 6 | 8 10 | 3½ | No sensible deflection. |

hard and porous nature, angular in shape, and of a size no larger than will pass through a riddle of 8 meshes to the foot; the pieces should be of various sizes, varying from the stated maximum size to a minimum size, which will fail to pass through a riddle of 4 meshes to the inch.

The secret of good concrete is a happy proportion of various sizes, so as to ensure all the interstices formed by the larger constituents being filled up by the smaller ones.

No dust, greasy, fatty, or other organic matter, should be allowed to mix with the concrete, as they will prevent the intimate adherence of the concrete to the aggregate.

For fire-resisting purposes the best constituents are broken pieces of fireclay, silica, bricks, retorts, or slag.

*Note.*—Cinders and gravel should not be used. The proportion of aggregates to cement should be three parts of calcined aggregate, one part of pure white granite sand, and two parts of cement.

## CHAPTER XXVIII.

### PREPARATIONS TO RENDER FABRICS AND OTHER INFLAMMABLE ARTICLES INCOMBUSTIBLE.

For upwards of a century chemists have sought for a process to render fabrics perfectly incombustible, yet, although the attempts in this direction have often been successful, the inventions have only in very rare instances been applied. In the year 1824 the principal theatre at Munich was destroyed by fire; the disaster was so great that Fuchs, a Bavarian, directed his attention to the subject of rendering dresses incombustible. He communicated his investigations in a paper to the Royal Academy at Munich in the same year. His process consisted in coating the articles to be protected with a solution of silicate of soda to the consistence of syrup, allowing it to dry and repeating the application as often as may be necessary. The efficiency of the process has been proved by numerous experiments to be very great.

Dr. Percy states that some years ago there was an interesting performance at Cremorne Gardens, London, by a man called the Fire King; there was an arched structure of iron lattice-work open at both ends, high enough for a man to stand upright within; there were also two side openings facing each other in the centre; the whole was covered with easily inflammable twigs, wood shavings, &c., which on ignition blazed up with great rapidity. The performer walked to and fro within the structure while it was all in a blaze; he had wide trousers, and a loose hood covering his head and descending to his hips, in the upper part of which were eye-holes protected by mica plates. Before the performance his dress appeared to have been well wetted in every part, but afterwards it appeared to be coated with a white, light, pumice-like substance. Dr. Percy secured some of this substance and found it to consist of silicate of soda, the identical substance recommended by Fuchs.

Lately, a fire-extinguishing solution has been introduced by a Mr. Winderspergu, and experiments have been tried with this solution at Portsmouth by direction of the Admiralty. The principal agent of this solution is the identical water-glass, or an aqueous solution of silicate of soda.

The following is a list of various solutions which have been brought out; all are more or less effective. It may stimulate manufacturers to practically apply one or other of the remedies described to render their manufactured goods incombustible, a desirable improvement to the clothing of persons engaged in occupations necessitating a constant and close contact with fire.

Maugham's preparation (patent expired).—After the water is decanted off at the end of the process usually practised for making starch, and before the starch is dry, phosphate of ammonia in the proportion of 480 grains to 1 ounce of moist starch must be mixed with it; the starch is then ready for use. Or if the starch is already made and has become dry, 600 grains of the salt to 1 ounce of starch. These ingredients are then to be incorporated by grinding them together, or by any other method of trituration that may be found convenient.

Charlton and Christian's preparation (patent expired).—An aqueous solution of hydrochlorate of baryta, or chloride of barium alone, or mixed with starch, flour, farina, or other sizing material.

Dembinsky and Engert's composition (patent expired) consists of sulphuret of potassium, silica, ground quartz or flint, soda of commerce, powdered charcoal, pyro-oxalic acid; the whole of these ingredients are mixed and reduced to a flux under heat, the flux is afterwards diluted with boiling water down to the consistency required for use.

Versmann and Oppenheim's preparation for rendering timber incombustible (patent expired).—Outside of the timber, to a certain depth, should be saturated with chloride of zinc, and afterwards it may be painted or coated with silicate of soda if required.

Delfosse describes his invention for preserving and rendering uninflammable wood, stuffs, and other fabrics as follows: "I place the wood in a stout metal vessel and inject a current of steam into it, I then create a vacuum to extract the pith and moisture from the wood, and admit a solution of sulphuret of calcium, which enters into and penetrates all the pores of the wood; I also admit a solution of sulphate of iron which decomposes the sulphuret of calcium, and transforms it into sulphate of lime and sulphuret of iron, both of which being insoluble mineral compounds protect the wood from rot and render it uninflammable. In order to render it still more incombustible it may be treated with a third preparation of an acid solution of borate of soda. To render stuffs and fabrics uninflammable I submit them to a solution of basic ammonia." The patent right for this invention has expired.

Henry Ellis's preparation (patent expired).—80 parts soda or potash silicate of magnesia, 15 parts soda or potash silicate of lime, 2 parts soda or potash silicate of alumina, 3 parts soda or potash silicate of iron—100 parts; brought to a specific gravity of 1·2. The solutions to be diluted by the addition of from 10 to 20 or more parts of water; the fabric is to be steeped, and before dried it is to be again steeped in another solution made of 10 parts of alum dissolved in 100 parts of water.

Lattas's invention (patent expired).—3 parts solution of starch, 1 part salts of soda, either chloride carbonate or phosphate. Instead of salts of soda, a like proportion of sulphate, carbonate, or chloride of magnesia may be used, the starch being prepared of a suitable consistency in the usual way; or 1 part of sulphate of alumina, combined with salts of potash or soda, with 2 parts of starch in solution. The articles to be steeped in solution.

Gratton and Rowbotham's preparation (patent expired).—Bi-borate or borate of soda, or of potash, magnesia, or other base mixed with gum of any kind; to this may be added as required a portion of carbonate of soda, potash, or magnesia, according to the base used, which tends to neutralise any excess of boracic acid, and therefore destroy corrosive quality. This is thoroughly incorporated with starch, and well ground and dried and used as ordinary starch is used.

O. Connor's invention.—A solution composed of either muriatic, sulphate, carbonate, or chloride of magnesium in combination with 10 per cent. of bromine. A quantity equal to 20 parts by weight of the above, is dissolved in

80 parts of water forming a solution in which the goods or fabrics are soaked, so as to become saturated.

MM. Martin and Tisser, Paris, have lately introduced the following preparations for rendering incombustible all kinds of inflammable substances, such as woven and other fabrics, of cotton, and other fibrous materials, paper, &c. The primary composition which may be applied to all kinds of fabrics without deteriorating them in the least, consists of sulphate of ammonia, pure, 8 parts; boracic acid, 3 parts; borax, 1·7 parts; water, 100 parts. The solution is to be placed in a vat (120° Fahr.) at the end of a paper-making machine, and the paper as it leaves the machine is passed through the solution in this vat, so as to be completely impregnated therewith; after which it is dried upon a warm cylinder and then wound on a reel.

If the paper is printed or in sheets it is simply to be immersed in the above solution, heated to 120° Fahr., spread out to dry, and afterwards pressed to restore the glaze destroyed by moisture. The above compositions ensure a high degree of incombustibility.

The following is an analysis of a preparation invented by M. Fobacci for rendering timber both incombustible and imperishable: sulphate of zinc, 55 lbs.; American potash, 22 lbs.; alum with ammoniacal base, 44 lbs.; oxide of manganese, 22 lbs.; sulphuric acid, at 60° Fahr., 22 lbs.; river water, 55 lbs. With the exception of the sulphuric acid, the whole of the above agents are to be poured into an iron boiler containing the above quantity of water at the temperature of 113° Fahr.; as soon as the substances are dissolved the sulphuric acid should be poured in little by little. For the application, the timber should be placed in the mixture and the whole boiled for three hours.

The following preparations applicable to wood and fabrics will be found very effective: the former consists of a mixture of borax and sulphate of magnesia, prepared by dissolving 3 parts by weight of borax and 2¼ parts of Epsom salts in 20 parts of water. On applying this mixture to timber, borate of magnesia is formed in the fibres of the timber which they envelope; this salt is insoluble in cold or hot water, and the fibres being enveloped in this salt, the flames cannot seize upon them.

For fabrics.—A mixture of sulphate of ammonia and sulphate of lime or gypsum, in different proportions, according to the intended use for fine or coarse goods. The sulphate of lime forms with the ammoniacal salt a double sulphate. The fibres should be completely enveloped with the mixture. The salt is not only proof against fire, but in the presence of great heat it has the quality of evolving ammoniacal gas, which suffocates the fire.

For timber, 2 parts of gypsum may be employed, and woodwork simply painted with this mixture will be found effectual in rendering wood comparatively proof against fire. The salts should be painted over with silicate paints to prevent their being washed out. Woodwork strongly impregnated with tungstate of soda or silicate of soda by treatment in a strong aqueous solution of these salts will be found quite uninflammable.

According to 'Les Mondes,' paper can be made proof against fire and water by the following preparation: one-third of ground asbestos fibre, mixed with two-thirds of paper waste in a solution of common salt and alum. Pass the mixture into a machine, plunge the paper thus made into a bath of dissolved gum lac and send it through the finishing rolls, when it may be cut into sheets. The salt and alum increase the strength of the paper, and its resistance to the action of fire. The lac renders it impermeable to moisture without interfering with its fitness for the reception of ink. Carbonate of ammonia, 2·5 parts; boracic acid, 3·0 parts; borax, pure, 1·7 parts;

starch, 2·0 parts; water, 100·0 parts. All that is necessary is to steep the fabrics in a hot solution composed as above until they have become impregnated, after which they are to be drawn and dried sufficiently to enable them to be ironed or pressed, like ordinary starched goods.

A second composition, applicable to theatrical scenery, woodwork, door and window frames, furniture, &c. It is to be applied hot, with a brush like ordinary paint. It is composed of boracic acid, 5 parts; hydrochlorate of ammonia or sal-ammoniac, 15 parts; potassic feldspar, 5 parts; gelatine, 1·5 parts; size, 5 parts; water, 100 parts; in which is added a sufficient quantity of a suitable calcareous substance to give it sufficient consistency or body.

A third composition, applicable to all kinds of canvas, sails, cordage, wood, &c., is applied by immersing the articles therein or by imbibition, and consists of hydrochlorate of ammonia or sal-ammoniac, 15 parts; boracic acid, 6 parts; borax, pure, 3 parts; water, 100 parts.

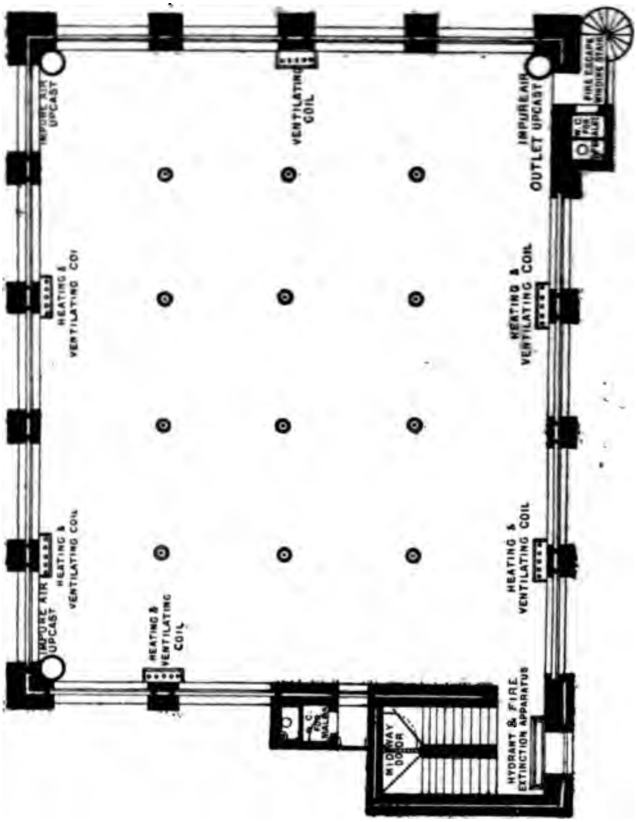
## CHAPTER XXIX.

### A MODEL INDUSTRIAL STRUCTURE.

### *Description of Figs.* 180 *and* 181.

Figs. 180 and 181 represent a plan and section of a mill constructed on the principles elucidated in the foregoing pages.

To ensure a dry foundation the subsoil is drained. In order to prevent the ascension of the subsoil gases into the rooms of the mill the whole site of the structure is covered with a layer of Portland cement concrete 6 inches in thickness, and immediately above the footings of the walls and column foundations an impermeable and perforated damp-proof course is inserted. To form the ground floor, arches of Portland cement concrete are used, supported by the column foundations and sleeper walls, and the space between the concrete layer and the soffits, or underside of the arches, supplies the necessary ventilated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MIDWAY DOOR
HYDRANT & FIRE EXTINCTION APPARATUS

Fig. 180.

space. The interiors of the columns are connected with the ventilated space by means of vents built in the column foundations, so that in case of fire the air currents passing up the interior of the columns would prevent the column

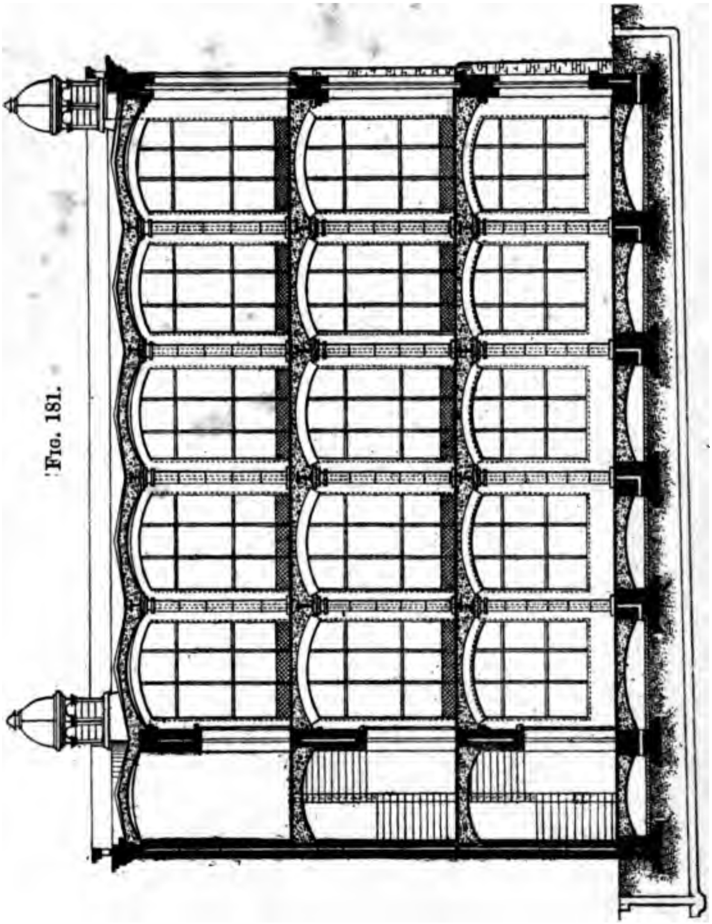
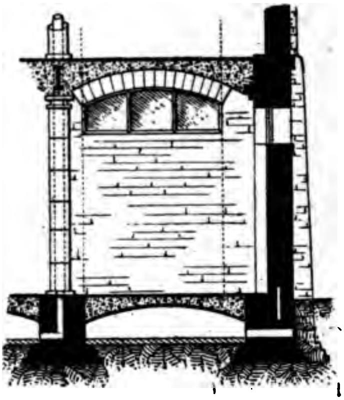


FIG. 181.

from becoming dangerously overheated. As a further precaution in case of fire, the columns are encased with terracotta, with ornamental capitals, which considerably enhance the appearance of the rooms.

The principle of concentrated strength is embodied in the construction of the external walls. Opposite each line of column supports the walls are erected in the form of piers or buttresses; the space intervening between each pier is entirely utilised for natural illuminating purposes. The window-frames are of iron, protected with magnetic oxide. In case of warehouses for the storage of goods, great illuminating areas are not so necessary, and wall space is valuable; the walls should, therefore, be constructed in the manner shown (see Fig. 182); this would allow the wall space to be utilised with this fire-resisting precaution—that the height of the stored goods should never exceed the height of the window sills. To return. All internal walls are of brick, and have a cavity which extends from damp-proof course to the height of the

FIG. 182.

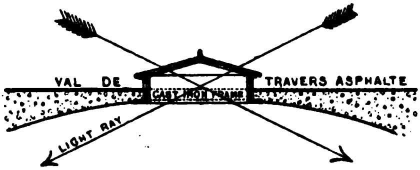


eaves. This precaution is valuable, alike on sanitary and fire-resisting grounds.

The floors are formed of concrete arching, the concrete constituted of Portland cement and calcined aggregate. Wrought-iron rolled joists, totally encased with concrete, support the arching; the upper surface of the floors are formed of Val de Travers or Seyssel asphalte. Those portions of the floors where the workpeople constantly stand are covered with spruce boards embedded in the asphalte. This precaution will be found beneficial to the health of the workers.

The roof is also formed of concrete arching; the upper surface is formed into ridges and valleys, in order to accelerate the flow of the rain-water into the outlets and fall-pipes. When extra illumination is required, it is wisdom to form skylights in the roof arching; this can easily be done, as shown. (See Fig. 183.)

Fig. 183.



As a further precaution from danger of fire in adjoining buildings, parapets are built along the eaves.

The stair towers project from the main structure; the steps are formed of hollow fireclay or some other refractory substance, and are supported at each end. The stairs are so arranged as to allow quick and easy ingress and egress. To prevent the stairway from becoming a medium for propagating fire, a self-closing and fire-resisting door is fixed midway between each storey; these doors, on leaving the premises at night, should always be left closed.

The water-closets are also built in a tower projecting from the main structure; the approaches to them are by means of external landings. Noxious gases, therefore, are not likely to enter the building. The closets are constructed on the principles recommended, and the soil pipe is double. The inner or soil tube is formed of block tin, and the outer tube of lead; and the soil pipe is continued above roof, where it may be surmounted with Kite's, Boyle's, or Weaver's exhauster. The soil pipe delivers its contents into Potts' Edinburgh trap, and thus the sewer gases are effectually cut off.

The private communicating sewer is arranged and fixed as recommended, and the sewage has an easy flow to the main sewer. Two water-closets, entirely separated, should be provided for each storey, one for males and the other for females.

Ventilation and warmth are secured by means of Weeks' hydro-caloric batteries, heated by steam or hot water, uniformly distributed throughout the rooms. The fresh air enters from the outside through the walls into the heating coils of the batteries, where it is warmed to any temperature desired by merely regulating the steam or hot-water valve connected to each battery.

The air outlet shafts are placed at each corner of the structure, and the necessary exhaust may be obtained either by fans or cowls, as desired.

The water mains are fixed in the stair tower, with hydrants and cases containing fire extinguishing apparatus on each landing.

To provide additional means of escape in case of fire, a winding stairway is fixed externally at the opposite corner to the stair tower.

A mill thus constructed would be perfectly sanitary, fire resisting, and safe, and would last for ages without any appreciable deterioration.

# CHAPTER XXX.

## A SOCIETY OF TEXTILE INDUSTRY FOR GREAT BRITAIN.

AT Mulhouse, textile and other manufacturers have formed themselves into a society, entitled La Société Industrielle de Mulhouse, for the mutual interchange of ideas, and the promulgation and criticism of all subjects of industrial interest. The society not only discriminates as to the value of all inventions and improvements that bear directly upon the economical, artistical, and mechanical means of production, but it has a branch association which considers means for the prevention of accidents (entitled Association pour Prévenir les Accidents de Machines), and the questions of the sanitary condition of factories, and the prevention of fire, are all subjects which are well considered.

The manufacturers of Mulhouse, by their spontaneous regard for the health of their workpeople, have prevented legislative interference with their freedom of industry. Had British manufacturers shown a similar regard for the health of the British operative, they might not now have been trammelled with legislative enactments, which press heavily upon them in face of competition with manufacturers having complete industrial freedom.

In England we have the Iron and Steel Institute, which has an incalculable effect in preserving the condition of the industry it represents; and lately another society has been formed under the name of the Society of Chemical Industry, and will undoubtedly have a great and good effect on the condition of that industry. What is required is a British Society of Textile Industry, formed on the lines of that of Mulhouse, which should not only be open to receive models and descriptions of inventions bearing on textile manufacturing, but should consider the health and fire-resisting character of the hives of industry. Such a society would not only have an immense influence in stimulating invention and preserving the health and safety of the workpeople, rendering legislative interference unnecessary, but would preserve and even improve the condition of the British textile industries.

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9. „ „ „
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21, 22. Clarke's Patent Hydraulic Differential Accumulators.
23. Clarke's Patent Hydraulic Truck Hoist.
24—26. „ „ „ Grid.
27—32. „ „ Canal (French) Lift.
33. Hydraulic Short Ram Lift.
34. „ „ „ „
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46. „ „ „ Patent.

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48. „ „ „ „
49. „ „ „ or Passenger Lift.
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